DOCUMENT RESUME

ED 190 835 CE 026 346

AUTHOR	Stanfield, Carter: And Others
TITLE	REACH. Heating Units.
INSTITUTION	Georgia Univ., Athens. Div. of Vocational Education.
SPONS AGENCY	Georgia State Dept. of Education, Atlanta. Div. of Vocational Education.: Office of Education (DHEW), Washington, D.C.
PUB DATE	Jun 80
NOTE	248p.: For related documents see CE 026 345-355.
EDRS PRICE	MF01/PC10 Plus Postage.
DESCRIPTORS	Electrical Occupations: Electricity: *Electromechanical Technology: *Heating: *Individualized Instruction: Instructional Materials: Learning Activities: Mechanical Skills: Postsecondary Education: *Trade and Industrial Education: Units of Study

ABSTRACT

As a part of the REACH (Refrigeration, Electro-Mechanical, Air-Conditioning, Heating) electromechanical cluster, this student manual contains individualized units in the area of heating. The instructional units focus on electric heating systems, gas heating systems, and oil burning systems. Each unit follows a typical format that includes a unit sheet, information sheets, assignment sheets, and job sheets. The unit sheet is designed to guide the learner through each task and is comprised of two main sections. The first lists all information needed to identify the task and the sequence in which activities are performed. The second section identifies each activity. (Related teacher's guides are available as CE 026 352, CE 026 354-355.) (LRA)

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REACH

HEATING UNITS

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OFFICE OF VOCATIONAL EDUCATION
GEORGIA DEPARTMENT OF EDUCATION
ATLANTA, GEORGIA 30334
CHARLES MCDANIEL, STATE SUPERINTENDENT OF SCHOOLS

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OF

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JUNE, 1980

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HEATING UNITS

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GAS HEATING SYSTEMS HE-09 - HE-18	NORMAN NESMITH, THOMAS TECH
OIL BURNING SYSTEMS HE-19 - HE-29	WARREN RAY, VALDOSTA TECH

HEATING UNITS

TEXT ASSIGNMENT SHEET

ASSIGNMENT NO.	TEXT NO.	PAGES	STUDY ASSIGNMENT
HE-01a	2	735	Read paragraph 20-34 "Electric Heat."
		640	Read paragraph 20-46 "Radiant Lamps and Glass Panel Heaters."
HE-02a	2	533-536	Read the section on electric furnace.
	1	738	Study the wiring diagram.
HE-03a			No text assignment.
HE-04a	2	721-722	Read paragraph 20-17, "Fuel Gases."
HE-05a			No text assignment.
HE-06a	2	665-666	Read paragraph 18-43 and examine illustrations.
HE-07a			No text assignment.
HE-08a			No text assignment.
HE-09a			No text assignment.
HE-10a	2	722-724	Read section 20-18 "Pilot Lights and Electric Ignition," section 20-19 "Thermocouple Circuits," and section 20-20 "Gas Controls."
	2	511-512	Read "Pilot" to "Main Gas Valve."
HE-11a	1	512-515	Read "Main Gas Valve to "Venting."
HE-12a			No text assignment.
HE-13a			No text assignment.
HE-14a	1	520-521	Read "Combustion Air" and study illustrations A-D.
HE-15a			No text assignment.
HE-16a			No text assignment.
HE-17a	2	727	Read section 20-24, "Furnace Inspection (Warm Air)."
HE-18a			No text assignment.

HEATING UNITS

TEXT ASSIGNMENT SHEET

ASSIGNMENT NO.	TEXT NO.	PAGES	STUDY ASSIGNMENT
HE-19a	5	3-8	Read pages and study illustrations.
HE-20a	5	169-172	Read the following sections, "One and Two-Pipe Systems," and "Distinction Between One and Two-Stage Pumps."
HE-21a			No text assignment.
HE-22a	4	122-129	Read sections and study illustrations of transformers.
HE-22b	4	143-148	Read sections and study illustrations of electrodes.
HE-23a	2	711-712	Read section 20-9, "Gun Type Oil Burner Pumps" and study illustrations.
HE-23b	4	101-110	Read sections and study illustrations on fuel pumps.
HE-24a	4	168-175	Read sections and study illustrations on motors.
HE-24b	4	75-77	Read sections and study illustrations on drive couplings.
HE-24c	4	77-79	Read sections and study illustrations on fans or blowers.
HE-25			No text assignment.
HE-26a	4	153-157	Read and study diagrams.
HE-26b	4	193-194	Read "limit Controls."
HE-26c	4	154-167	Review diagrams of controls (no reading assignment).
HE-27a			No text assignment.
HE-28a			No text assignment.
HE-29a	1 2	541-545 867,742, 744	Read pages 541 through 545, section on humidifiers. Read paragraph 24-41 also paragraph 20-50 through 20-53.

MAJOR BLOCK Heating **NAME**

TASK Electric Heating Systems

UNIT Applying Principles of Electric Furnaces and Controls **TIME (est.)** **(act.)**

UNIT NO. HE-01

OBJECTIVE(S)

Demonstrate a knowledge of the principles involved in the operation of electric furnaces and controls.

START ➡ W-1 A-1 W-2 C-1 L-1 C-2 W-3 C-3 L-2 C-4

WRITTEN ASSIGNMENT(S)

W-1 Text Assignment HE-01a
W-2 Assignment Sheet HE-01a
W-3 Assignment Sheet HE-01b
W-4
W-5
W-6
W-7

AUDIOVISUAL(S)

A-1 Slide Set HE-01a
A-2
A-3
A-4
A-5
A-6
A-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-01a
L-2 Job Sheet HE-01b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5
C-6
C-7
C-8
C-9

Answer the following questions about the diagram below. Further review of the reading assignment and the slide presentation may be required.

1. List the operational sequence for this diagram.

2. What protective devices are used to protect the strips?

3. What type of coils do the sequencers have?

4. What controls the fan motor?

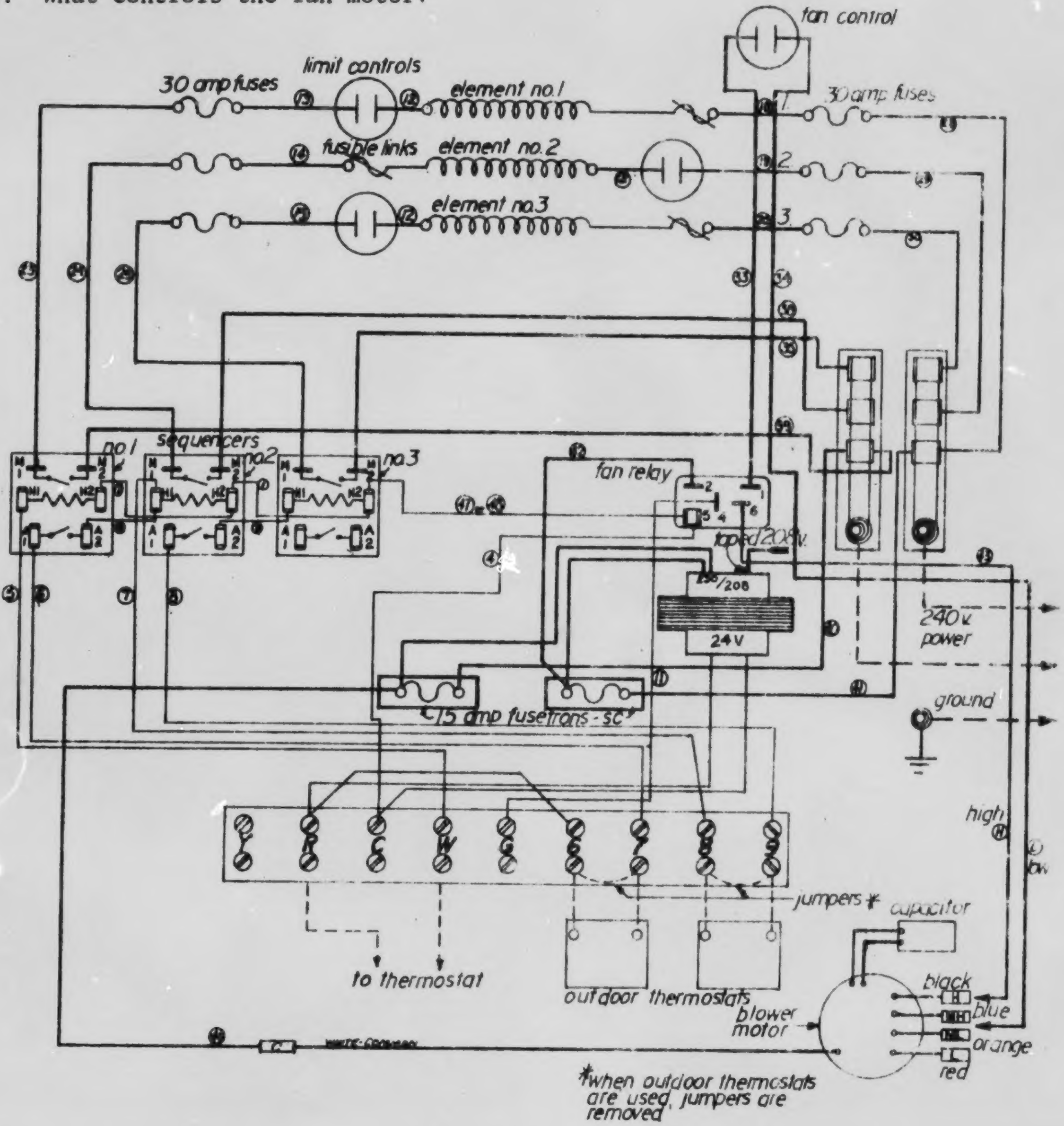

fan control
limit controls
30 amp fuses
element no.1
30 amp fuses
fusible links
element no.2
element no.3
no.1
sequencers
no.2
no.3
fan relay
taped 208v.
230/208
24 V
240v. power
ground
15 amp fusetrons - sc
R
C
W
G
6
7
8
9
jumpers*
to thermostat
outdoor thermostats
high
low
capacitor
black
blue
orange
red
blower motor
*when outdoor thermostats are used, jumpers are removed

FIGURE A

Turn on the electric furnace assigned by the instructor. Using the appropriate meters and the unit's wiring diagram, record the necessary information into the chart below.

Fan Current ____________________
Fan Voltage ____________________
Element Current (individual) ____________________
Element Current (total) ____________________
Element Voltage ____________________

1. What controls the blower motor?
2. When does the blower engage?
3. When does the blower shut off?
4. How many heat strips are present?
5. What is the rating of each strip?
6. Describe the sequence in which the strips turn on and go off.

Draw a schematic diagram for an electric furnace with,

A. 3 heating elements
B. 1 element and fan to energize immediately upon demand
C. 2 other elements to be step-sequenced
D. Current overloads
E. Fusible links
F. Thermal overloads
G. Controlled by 24v thermostat

1. Wire the electrical circuit designed in Assignment Sheet HE-01b on the unit assigned by the instructor.
2. Ask the instructor to check the wiring.
3. Operate the furnace and check the following:
    - A. strip sequencing
    - B. amp draw of strips
    - C. fan operations
    - D. shutdown sequencing

MAJOR BLOCK Electricity **NAME** ____________

TASK Electric Heating Systems

UNIT Installing Electric Furnace **TIME (est.)** ______ **(act.)** ______

UNIT NO. HE-02

OBJECTIVE(S)

Install an electric furnace using manufacturer's installation instructions and wiring charts.

START ➡ W-1 ➡ W-2 ➡ C-1 ➡ L-1 ➡ C-2

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Text Assignment HE-02a	**A-1**	
W-2	Assignment Sheet HE-02a	**A-2**	
W-3		**A-3**	
W-4		**A-4**	
W-5		**A-5**	
W-6		**A-6**	
W-7		**A-7**	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-02a	**C-1**	Instructor Check
L-2		**C-2**	Instructor Check
L-3		**C-3**	
L-4		**C-4**	
L-5		**C-5**	
L-6		**C-6**	
L-7		**C-7**	
L-8		**C-8**	
L-9		**C-9**	

Read the installation instructions for the furnace assigned by the instructor. Look for the following information and record below.

A. How may the furnace be positioned?

B. Clearance spaces.

C. Type of thermostat and wiring.

D. Type and size of power wiring.

Review the National Electric Code regarding the wiring to the furnace and determine if manufacturers and N.E.C. requirements match.

Read the installation instructions for the furnace assigned by the instructor. Install the furnace assigned by the instructor. This includes:

A. Setting unit, if necessary.

B. Power wiring to unit.

C. Control wiring to unit.

D. Thermostat installation.

MAJOR BLOCK Heating **NAME**

TASK Electric Heating Systems

UNIT Troubleshooting Electric Furnaces **TIME (est.)** **(act.)**

UNIT NO. HE-03

OBJECTIVE(S)

Use an operational sequence and troubleshoot electric furnaces.

START ➔ A-1 ▷ W-1 ▷ C-1 ▷ L-1 ▷ C-2 ▷

WRITTEN ASSIGNMENT(S)

W-1 Assignment Sheet HE-03a
W-2
W-3
W-4
W-5
W-6
W-7

AUDIOVISUAL(S)

A-1 Slide Set HE-03a
A-2
A-3
A-4
A-5
A-6
A-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-03a
L-2
L-3
L-4
L-5
L-6
L-7
L-8
L-9

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3
C-4
C-5
C-6
C-7
C-8
C-9

The instructor will assign three heating units for this activity. Obtain a wiring diagram for each unit to troubleshoot. Study the diagrams and make an operational sequence list for each.

Unit #1

Unit #2

Unit #3

Job Sheet HE-03a

Troubleshoot three electric furnaces assigned by the instructor. Be sure to follow a logical procedure. Check primarily with a volt meter and an amp meter. Use an ohmemter if and when the problem has been isolated with a volt meter and/or ampmeter. Fix the problems if the instructor so directs.

	Serial Number	Problem	Repair Made Yes/No
Unit #1			
Unit #2			
Unit #3			

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Applying gas fuel combustion and safety principles **TIME (est.)** **(act)**

UNIT NO HE-04

OBJECTIVE(S)

To develop a safety consciousness in installing and working with gas fired heating systems.

START ➔ W-1 ▷ W-2 ▷ C-1 ▷ L-1 ▷ C-2 ▷ W-3 ▷ A-1 ▷
W-4 ▷ W-5 ▷ C-3 ▷ W-6 ▷ W-7 ▷ C-4 ▷ L-2 ▷ C-5 ▷

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-04a
W-2 Assignment Sheet HE-04a
W-3 Information Sheet HE-04b
W-4 Text Assignment HE-04a
W-5 Assignment Sheet HE-04b
W-6 Information Sheet HE-04c
W-7 Assignment Sheet HE-04c

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-04a
L-2 Job Sheet HE-04b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-04a
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 Instructor Check
C-6
C-7
C-8
C-9

The first step towards understanding gas-fired furnaces is to become familiar with the various types of fuels. To understand the subtle design differences in gas heating equipment, one must first understand the chemical and physical properties of the several products which generally fall under the broad classification of gaseous fuels.

There are four major categories of gaseous fuels which can be subdivided into the various products currently being used for heating purposes. Products in each category exhibit similar, but not necessarily identical physical and chemical properties. These four general categories, in relative order of use are,

1. natural gas
2. liquid petroleum gas
3. mixed gas
4. manufactured gas

Natural gas is relatively recently accepted, yet it is the most widely used of the four types. Its physical properties make it desirable as a fuel. It has a boiling point of approximately -285°, which makes gas pressure possible virtually anywhere in the world. It has a specific gravity ranging from 0.5 to 0.65, which allows natural dispersion and venting of the gas. Natural gas derives its name from its origin. It is a mixture of combustible gases created through chemical decomposition underground. The principle component of natural gas is methane but it also contains small amounts of other types of gases such as ethane, propane, butane, pentane, hexane, carbon dioxide, oxygen, and nitrogen. For a breakdown of the chemical components by geographical location, see Figure A. The oxidation of this mixture of gases yields from 1000 to 1075 B.T.U. per cubic foot of gas.

Liquid petroleum, commonly called L.P., runs second in terms of overall usage, but is more prevalent in rural areas than any other gaseous fuel. L.P. may be broken down into several different types of products, however, only propane and butane are commonly used for heating. Recently, many other types of L.P. gases have come into use but none of the new products have been applied to the heating industry.

Propane mixtures which cover the majority of L.P. gases used today, have a boiling point of approximately -40°F. This makes the use of propane possible in most parts of the world. Its specific gravity is approximately 1.52. This is a disadvantage as far as dispersion and venting are concerned because it is heavier than air. Propane, in the form delivered to the customer's house, is actually a mixture of liquids under pressure. It is produced by refining oil and natural gas. This mixture consists mostly of propane, but contains various other gases such as ethane, ethylene, and propylene. For a breakdown of a typical propane mixture see Figure B. When one cubic foot of this mixture is burned, it produces between 2500 and 2550 B.T.U.'s of heat.

FIGURE A

CITY	Methane CH_4	Ethane C_2H_6	Propane C_2H_8	Butane C_2H_{10}	Pentane C_2H_{12}	Hexane C_6H_{14}	CO_2	N_2	Specific Gravity	BTU per cu ft, Dry' (Gross)
Akron, OH	88.00	8.10	0.40	0.20	0.10	0.10	0.70	2.30	0.614	1052
Atlanta, GA	94.95	1.30	0.33	0.10	0.09	0.14	0.70	2.39	0.5974	1008
Baltimore, MD	93.80	3.60	9.90	0.70			0.60	0.40	0.602	1062
Canton, OH	88.00	8.10	0.40	0.20	0.10	0.10	0.70	2.30	0.614	1052
Cheyenne, NY	72.40	5.70	3.40	1.20	0.20	trace		17.10	0.700	971
Cincinnati, OH	93.70	3.90	0.60	0.10			0.80	0.90	0.605	1071
Cleveland, OH	88.00	8.10	0.40	0.20	0.10	0.10	0.70	2.30	0.614	1052
Columbus, OH	95.70	2.90					1.30	0.10	0.600	1037
Dallas, TX	85.00	7.10	2.40	0.50	0.40		0.60	4.00	0.650	1079
Denver, CO	73.70	5.40	3.30	1.20	0.10		0.15	16.15	0.692	973
Detroit, MI	71.70	14.50					0.10	13.50	0.690	999
Houston, TX	93.94	2.88	0.69	0.44	0.13		1.30	0.62	0.605	1069
Kansas City, MO	79.21	4.54	2.71	1.53	0.48	0.12	0.10	11.31	0.684	1024
Los Angeles, CA	85.10	7.40	3.10	0.40	0.10		0.10	3.80	0.648	1089
Memphis, TN	92.80	4.20	0.80	0.20	0.10	0.10	1.00	0.80	0.600	1049
Milwaukee, WI	72.20	6.30	3.80	1.00				16.70	0.703	975
Minneapolis, MN	72.02	15.55					0.10	12.26	0.681	1002
New Orleans, LA	92.89	3.23	1.15	0.59	0.24	0.19	0.49	1.22	0.611	1065
Oklahoma City, OK	83.23	7.91	2.82	0.75	0.43		0.24	3.66	0.679	1068
Omaha, NE	75.78	4.97	3.24	2.12			0.20	13.55	0.685	1011
Pittsburgh, PA	90.12	5.64	1.39	0.48	0.07	0.04	0.68	1.58	0.6176	1071
Pueblo, CO	74.90	5.20	3.20	1.10	0.10	trace	0.30	15.20	0.684	975
St. Louis, MO	87.60	7.40					1.00	4.00	0.610	1027
San Diego, CA	80.24	12.70	1.60	0.30	0.04		2.05	2.97	0.672	1083
San Francisco, CA	86.50	6.90	2.90	0.30	0.10		0.50	2.80	0.640	1090
Toledo, OH	95.70	2.90					1.30	0.10	0.609	1037
Tulsa, OK	78.44	13.72	1.35	0.47	0.05		0.20	4.57	0.603	1073
Washington, D.C.	87.40	7.10	2.80	0.90	0.40		0.20	1.20	0.630	1131
Wichita, KS	79.62	6.40	1.42	1.12	0.48	0.14	0.10	10.62	0.660	1051
Youngstown, OH	88.00	8.10	0.40	0.20	0.10	0.10	0.70	2.30	0.614	1052

Butane is much less common than propane, but is still used in some rural areas where mild climates exist. Use of butane boils at around 32°F, its use is restricted to fairly mild climates. Its specific gravity is 2.0 which makes dispersion and venting extremely difficult. Butane, used to heat homes, is actually a mixture of liquids, however, the largest portion is butane. Like propane, butane also contains a small amount of other gases and carbons and is the result of refining oil and natural gas. Butane mixtures contain about 3175 B.T.U.'s of heat per cubic foot.

Mixed gas, as the name suggests, is actually two or more types of gas mixtures. In areas with large natural gas demands, manufactured and L.P. gases are often added to the lines to increase the gas supply and to control the line pressure. Although natural, L.P. and manufactured gases are all mixtures, they are not referred to as mixed gases. Only when significant amounts of other gases are introduced can the product be considered a mixed gas. Due to its nature, mixed gas can contain an almost unlimited variation of gases. A very general specific gravity of 0.6 and a heat content of 600-800 B.T.U.'s per cubic foot of gas can be assumed for the majority of mixed gases.

Manufactured gas is the by-product of coke production. It was once widely used in large industrial centers, but (due to widespread use of natural gas) has lost its importance. The specific gravity of manufactured gas is approximately 0.6 and its heat content is 500-600 B.T.U. per cubic foot of gas.

TYPICAL PROPANE COMPOSITION

Chemical Name	Formula	Percentage
Propane	C_3H_8	87-98
Ethane	C_2H_6	1-3
Ethylene	C_2H_4	1-2
Propylene	C_3H_6	2-13

FIGURE B

Using the previous information sheets and illustrations, answer the following questions:

1. Name the four main categories of gaseous fuels. List them in order of usage, starting with the most prevalent.

   1.
   2.
   3.
   4.

2. What is meant by the term L.P.?

3. In the space provided fill in the specific gravity and circle the heaviest gas.

   1. Natural _____________ (specific gravity)
   2. Propane _____________ (specific gravity)

4. What is the boiling point of butane at atmospheric pressure?

5. List the approximate heat content values (B.T.U.'s) for each of the four major gaseous fuels.

6. Using the following chart compare and contrast mixed and manufactured gases. Be sure to cover their origin, heat content, specific gravity and usage.

	Mixed Gas	Manufactured Gas
1. Origin		
2. Heat Content		
3. Specific gravity		
4. Usage		

Using previous information sheets identify at least three different types of combustible gases used in the shop. Determine the characteristics of each gas and place in the chart below.

	1	2	3
(A) Type of Gas Used in Shop			
(B) Purpose of Use in Shop			
(C) Specific Gravity			
(D) Heat Content (B.T.U.)			
(E) Stored As Gas or Liquid			

The burning of any substance is known as combustion. Combustion is a term used to describe rapid oxidation. Oxidation is a chemical reaction between oxygen and some other substance that produces a new compound. An example of oxidation is the combination of oxygen and iron to form iron-oxide. A totally new compound is formed which contains both oxygen and iron. A more common term for this reaction is rust. As the chemical bond is broken, a small amount of heat is generated. The oxidation of iron occurs so slowly, however, that the heat generated is not noticeable. Although the process is similar, oxidation of iron is not usually referred to as combustion. Another example of oxidation is the reaction between carbon and oxygen which produces carbon-dioxide. This reaction usually occurs at a faster rate than does the iron-oxide compound. Because of the increased speed of reaction, great amounts of heat are generated within a short period of time. The term combustion may be applied to this reaction. The difference is in the speed of reaction, not necessarily in the quantity of heat which is generated.

Most gaseous fuels consist of various mixtures of hydrocarbons. When oxygen and hydrocarbons are combined, water and carbon-dioxide are produced. Both are extremely stable and safe compounds. But, if the reaction does not take place under ideal conditions (i.e. correct temperature and gas to air ratio) variable amounts of unstable and often toxic substances may be created because of incomplete combinations. Perfect, or ideal, combustion for several fuels is represented in Figure C.

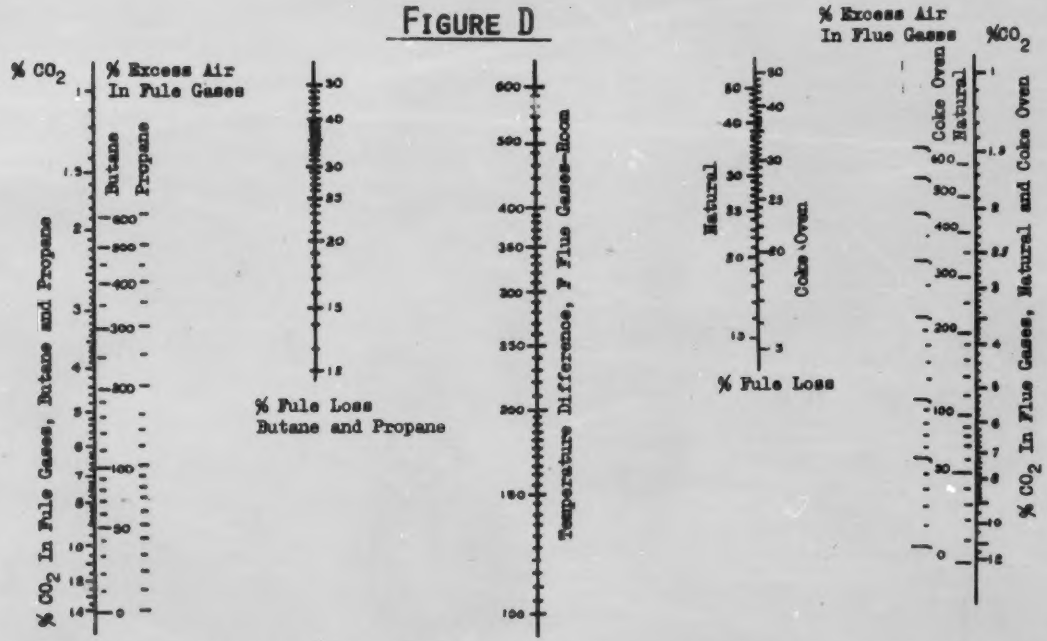
FIGURE C

Substance	Molecular Symbol	Chemical Reaction of Combustion	Ignition Temperature F Deg	Calorific Value						
				Btu per lb		Btu per Cu ft^b	Lb per Lb		Cu Ft per Cu ft	
				Gross	Net		O_2	Air	O_2	Air
Carbon (to CO)	-	$2C+O_2-2CO$	-	3950	-	-	1.33	5.76	-	-
Carbon (to CO_2)	-	$2C-2O_2-2CO_2$	-	14093	-	-	2.66	11.53	-	-
Sulfur (to SO_2)	-	$S+O_2-SO_2$	-	3983	-	-	1.00	4.29	-	-
Sulfur (to SO_2)	-	$2S+3O_2-2SO_2$	-	5940	-	-	1.50	6.43	-	-
Carbon Monoxide	CO	$2CO+O_2=2CO_2$	1166-1319	4347	-	321.8	0.57	2.47	0.5	2.30
Methane	CH_4	$CH_4+2O_2=CO_2+2H_2O$	1260-1380	23879	21520	1013.2	3.99	17.27	2.0	9.53
Acetylene	C_2H_2	$2C_2H_2+5O_2=4CO_2+2H_2O$	763-824	21500	20776	1499	3.07	13.30	2.5	11.01
Ethylene	C_2H_4	$C_2H_4+3O_2=2CO_2+2H_2O$	986-1123	21611	20295	1613.8	3.42	11.81	3.0	14.29
Ethane	C_2H_6	$2C_2H_4+7O_2=4CO_2+6H_2O$	990-1120	22320	20432	1792	3.73	16.12	3.5	16.68
Hydrogen	H_2	$2H_2+O_2=2H_2O$	1063-1166	60958	51571	325	7.91	34.34	0.5	2.39
Hydrogen Sulfide	H_2S	$2H_2S+3O_2=2H_2O+2SO_2$	599-608	7100	6545	647	1.41	6.10	1.5	7.15
Propane	C_3H_8	$C_3H_8+5O_2=3CO_2+4H_2O$	950-1080	21611	19944	2590	3.63	15.70	5.0	23.82
Butane	C_4H_{10}	$2C_4H_{10}+13O_2=8CO_2+10H_2O$	890-1020	22320	19680	3370	3.58	15.49	6.5	30.97
Commercial Propane	-	-	920-1020	21560	19865	2520	3.60	15.58	4.9	23.4
Commercial Butane	-	-	900-1000	21180	19591	3260	3.54	15.3	6.3	30.0

Some type of catylist is needed to cause a chemical reaction between oxygen compounds. This is what causes the reaction to take place. Heat serves as the catalyst for combustion of gases. Without sufficient heat, the reaction will not be complete. Likewise, since a definite ratio of oxygen to carbon and hydrogen is needed, insufficient oxygen supply will also produce incomplete combustion. Perfect combustion is caused when an exact amount of fuel and oxygen is combined at a sufficiently high temperature.

A perfect combustion process will have no left over fuel, oxygen, or unstable compounds. Since absolute perfection in the gas to air ratio is not possible, most gas appliances introduce excess combustion air to insure that no fuel or unstable compounds are left. Excess oxygen is left, however, and will result in slightly reduced combustion temperatures thus, less than 100 percent efficiency is achieved. For a breakdown of typical losses due to the introduction of excess air, see Figure D.

FIGURE D



While obviously not achieving perfect combustion, this assures complete combustion as all fuel is burned and no unstable compounds are produced.

Up to now, all combustion air has been treated as a single product. Actually the air enters the reaction at two separate levels. (1) Primary air refers to air which is mixed with the fuel before the fuel is ignited. (2) Secondary air refers to air which is drawn into the combustion process after the fuel has ignited. Air is introduced into the process at two levels because of the difficulty in maintaining an exact mixture of oxygen and fuel before combustion. Primary and secondary air is generally considered as a whole. Due to gas inconsistancies, air inconsistancies, and variable draft pressures; accurate calculations would be practically impossible.

Practice has shown however, that approximately ten cubic feet of combustion air per 1000 B.T.U.'s is needed for perfect combustion. Remembering that perfect combustion is not possible, most manufacturers design their equipment to operate with 14 cubic feet of excess air per 1000 B.T.U. is an industry standard.

The heat catalyst, is still required before complete combustion can take place. The absolute minimum temperature to be maintained in the combustion chamber is approximately 1200°F. Commercial gas is almost always diluted with various other gases. Its combustion occurs at 1200°F to 1220°F, however since excess air is introduced into the combustion chamber, most appliances actually operate around 1600°F to 1800°F.

Some harmful gases are produced as a result of incomplete combustion. Some of the toxic and noxious gases formed by incomplete combustion are carbon monoxide, aldehydes, ketone, and other hydrolated hydrocarbon compounds. All of these have pungent odors except for carbon monoxide. Unfortunately carbon monoxide occurs in far larger concentration and is odorless. If odors of aldehydes or ketones are present, it may be assumed that a large quantity of carbon monoxide also exists. Any condition resulting in the formation of these gases should be corrected immediately.

Assignment Sheet HE-04b

Answer the following questions. You may want to refer back to the text assignment or information sheets.

1. The combustion process in a gas fired furnace can best be represented by the formula,

		CATALYST	PRODUCT
a.	fuel + air	oxygen	carbon
b.	fuel + air	heat	carbon dioxide + water
c.	fuel + carbon dioxide	oxygen	water
d.	fuel + air	oxygen	carbon dioxide

2. The chemical reaction between a compound and oxygen to form a new compound is best described as,

   a. combustion
   b. complete combustion
   c. oxidation
   d. perfect combustion

3. Air mixed with fuel after combustion is called,

   a. secondary air
   b. primary air
   c. excess air
   d. none of the above

4. Excess combustion air,

   a. increase combustion efficiency
   b. decreases furnace efficiency
   c. should be eliminated
   d. all of the above

5. A bunson burner is an example of,

   a. non-luminous combustion
   b. luminous combustion
   c. non-aerated combustion
   d. spontaneous combustion

6. Fresh air which is mixed with the hot combustion gases before traveling up the flue is called,

   a. primary air
   b. secondary air
   c. excess air
   d. dilution air

A correctly operating gas furnace is one of the safest appliances available. However, improperly adjusted misapplied, poorly installed, or neglected gas heating equipment can be very dangerous. To prevent being poisoned, incinerated, asficiated, or dismembered service technicians should be able to recognize hazardous conditions in gas-fired equipment.

Most gaseous fuels are less toxic than the chemicals we eat in food and smear on our bodies in the form of beautifying agents. Propane and methane are less toxic than monochlorodifloromethane (R-22). Furthermore, the combustion products produced in a correctly adjusted gas furnace are carbon dioxide, water, and hot air.

How can these harmless chemicals poison us? They can't. However, carbon monoxide aldehydes, and ketones can. These are all products of incomplete combustion. If, for any reason, a furnace's combustion air is choked off, these harmful gases are produced.

The poisonous gases previously identified can be detected. The aldehydes and ketones will make their presence known by their bitter sweet aroma. Carbon monoxide has no distinguishable odor. It combines with the oxygen in the blood and forms carbon dioxide which robs the body of oxygen. This is a very dangerous condition and should be avoided at all costs. Besides carbon monoxide poisoning, large accumulations of gas may produce suffocation. Even though methane and propane are essentially non toxic, if they are allowed to replace the air in a closed area, suffocation may result from lack of oxygen. A small, closed off room with a large gas leak could pose a dangerous setting for inhabitants.

Imagine a cold winter night when John Doe closes all of his windows and doors to keep out the cold. When he goes to bed, he leaves his small space heater burning. During the night a gas pressure loss causes the flame to go out, but since the pressure loss was only momentary, the gas flow resumes. Unfortunately John's space heater is not equipped with a gas safety shutoff and during the night the gas replaces most of the air in the room. John suffocates.

Suppose his heater didn't go out, but burned all night. Eventually too little oxygen would be left to support complete combustion and carbon monoxide would be formed. The longer the heater burns the more carbon monoxide is formed. This condition may also result in death.

Never leave unvented gas appliances burning for long periods of time in closed areas. Even vented appliances are hazardous if outside combustion air is not brought in. The vent merely carries away combustion products. Enough opening must be provided to supply all the combustion air. Both humans and gas appliances need lots of oxygen.

Combustability is the most obvious hazard of gaseous fuels. Propane, methane, and butane are all fairly stable and safe gases. There is little danger of explosion in any atmosphere that is 100% gaseous fuel. However, if these components are mixed with large amounts of oxygen, a small spark could trigger a large explosion. Gas leaks in equipment lines can create a potential hazard. Gas equipment should be leak tested regularly and leaks should be repaired immediately. Natural gas has a built in safety factor which L.P. gases do not have. It's specific gravity makes it lighter than air, which makes large accumulation of gas improbable. L.P. gases have specific gravities heavier than air. Because of their weight, they tend to puddle up like liquids. This factor makes leaking L.P. appliances extremely hazardous.

A leak in an L.P. gas line could slowly fill a basement with gas. When the gas that accumulated to the point at which it reaches the pilot light on the furnace, an explosion may occur.

Fortunately, few people lose their lives as a result of hazardous gas appliances. Although fatal accidents occur more from electrocution in the home, gas is responsible for many deaths each year. Most of these accidents however, could easily have been avoided if appropriate precautions had been taken.

Assignment Sheet HE-04c

Design a checklist to be used for a visual gas safety inspection. Use all available resources provided in this unit.

Locate at least three gas-related safety hazards present in the shop. Recommend corrective action for each hazardous condition.

	Hazardous Condition	Recommended Corrective Action
1.	________________	________________________
		________________________
		________________________
2.	________________	________________________
		________________________
		________________________
3.	________________	________________________
		________________________
		________________________

MAJOR BLOCK Heating **NAME** ____________

TASK Gas Heating Systems

UNIT Demonstrate a Knowledge of Understanding Basic Gas Systems **TIME (est.)** ________ **(act.)** ______

UNIT NO HE-05

OBJECTIVE(S)

Identify components and functions of four basic gas heating systems.

START ➔ W-1 ▷ A-1 ▷ W-2 ▷ C-1 ▷ L-1 ▷ C-2 ▷ W-3 ▷ W-4 ▷ C-3 ▷ A-2 ▷ L-2 ▷ C-4 ▷

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-05a	**A-1**	Slide Set HE-05a
W-2	Assignment Sheet HE-05a	**A-2**	Slide Set HE-05b
W-3	Information Sheet HE-05b	**A-3**	
W-4	Assignment Sheet HE-05b	**A-4**	
W-5		**A-5**	
W-6		**A-6**	
W-7		**A-7**	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-05a	**C-1**	Instructor Check
L-2	Job Sheet HE-05b	**C-2**	Instructor Check
L-3		**C-3**	Instructor Check
L-4		**C-4**	Instructor Check
L-5		**C-5**	Instructor Check
L-6		**C-6**	
L-7		**C-7**	
L-8		**C-8**	
L-9		**C-9**	

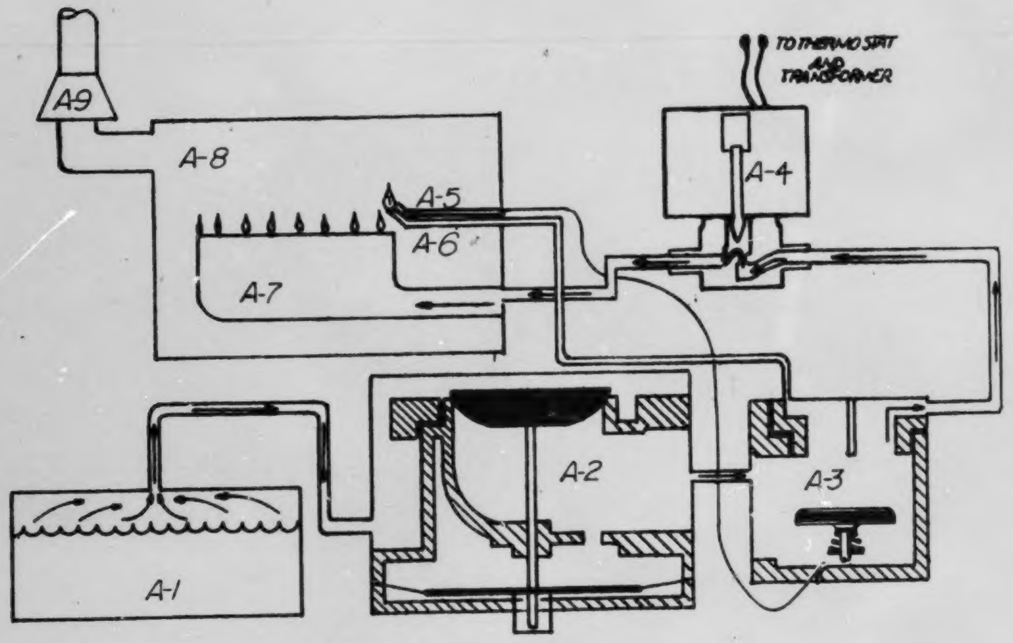
The type of combustion most people are familiar with is known as luminous combustion. A burning candle is an example of luminous combustion. It is called luminous combustion because of the large, bright flame. All of the combustion air required is drawn from around the flame and none if it is mixed with the fuel before combustion.

Non-luminous combustion; however, burns with a subdued dark blue flame with a small, light blue inner core. The gas fired furnace is an example of a non-luminous combustion apparatus. The combustion air for a gas furnace enters both before and after ignition, causing all the fuel to burn completely.

The candle also has no way of regulating its fuel or combustion air. It has no way of automatically igniting and extinguishing itself on demand, no separation of combustion air and tempered air, and no safety devices. In short, the candle represents every pitfall we wish to avoid in designing an efficient, convenient, and safe furnace.

A candle employs a non-renewable storage facility. When the wax is gone, the entire candle must be replaced. A gas furnace however, uses a refillable tank or a utility joined main gas line, both of which have easily renewable sources. The tank in Figure A-1 stores the fuel in a liquid state under pressure. The liquid turns to a gas when the pressure is reduced by opening the valve. When the tank becomes empty, it is renewed by the local gas dealer.

FIGURE A



A candle has no means of regulating its fuel, but as shwon in Figure A the gas furnace has a gas pressure regulator (A-2). The regulator receives the tank pressure necessary for storage and reduces it to a lower pressure where the unit can operate safely. By means of a diaphram and springs, the regulator supplies a constant stream of low pressure gaseous fuel to the unit. The regulator permits adjustment of gas pressure within a range of operating pressures. This will permit the furnace to control its fuel comsumption while the candle cannot.

The candle has no means of cutting its fuel supply off or on automatically. The furnace, on the other hand, employs a gas valve (A-4) which uses a solenoid to start and stop the flow of gas to the unit. The candle cannot extinguish itself if hot wax begins to overflow onto the candle holder. If the furnace malfunctions, the Basso switch (A-3) will shut down the gas supply and prevent any seepage of raw gas. The Basso switch is controlled by the thermocouple (A-5) in the pilot assembly (A-6) which senses the correct operation of the furnace.

Pre-combustion mixing of the fuel and combustion air does not exist in luminous combustion. This results in a cool, inefficient flame. The furnace; however, mixes primary air with the gas in the venturi of the burners (A-7). After ignition, secondary air is mixed with the flame to insure complete combustion.

The operator must light the candle everytime it is ignited. The automatic gas fired furnace utilizes a pilot light (A-6) which ignites the gas-air mixture as it comes out of the burner (A-7).

Combustion products contaminate the tempered air of a candle which releases the products of combustion into the atmosphere. The heat exchanger (A-8) permits all combustion products to remain separate from conditioned air. The products of combustion remain inside the heat exchanger, while the controlled air remains outside of the heat exchanger.

Candles offer no way of disposing unwanted combustion products. The furnace is provided with a flue (A-9) which removes all combustion products and carries them to an area where they are less offensive.

With a working knowledge of each component of Figure A a molecule of fuel can be traced through the system. The fuel starts as a liquid under high pressure; however, due to reduction in pressure the fuel vaporizes and enters the system in a gaseous state (A-1). It then moves down the line into the pressure regulator (A-2). Here the pressure is lowered by the combined effects of the diaphram and the spring. The fuel leaves the regulator under a low pressure and travels to the basso switch (A-3). Most of the gas is directed toward the gas solenoid valve (A-4), but a small portion it routed to the pilot burner (A-6). The heat from the pilot flame generates a small voltage in the thermocouple (A-5) which holds the BASSO switch open. Should the flame go out the voltage will cease and allow the spring loaded BASSO switch to close, this stops the flow of gas to the pilot burner (A-6). The gas then travels to the gas solenoid valve (A-4). Here its path is blocked by another spring loaded needle valve. During normal operation when the gas solenoid valve is energized the needle withdraws into the solenoid, and the gas can travel on to the manifold. The gas now escapes the manifold through the orifice which is located at the front of the burner.

The velocity of the gas creates a slight vacuum which draws primary air into the burner venturi where the gas and air are mixed. This mixture passes through the burner openings, where it comes into contact with the pilot flame and ignites. More air is drawn through the cabinet to insure complete combustion.

The fuel has now united with oxygen from the air to form carbon dioxide and water vapor. The hot gases escape the heat exchanger (A-8) through the draft diverter opening (A-9), where they mix with fresh dilution air. The total updraft is then carried into the heat exchanger (A-8). The heat exchanger absorbs the heat and transfers it to the surrounding air which is circulated throughout the heated area.

The molecule of gas has (1) vaporized, (2) reduced in pressure, (3) diverted through the basso switch, (4) the gas valve, (5) pilot assembly, (6) mixed with primary air,. (7) ignited, (8) mixed with secondary air, (9) became carbon dioxide and water vapor, (10) released heat, (11) mixed with dilutor air, and (12) traveled up the flue. The heat was transferred to the air circulating through the house while the by-products were carried outside.

Assignment Sheet HE-05a

Label each component in the diagram in the space provided, and explain what physical and/or chemical changes are taking place at that point in the system.

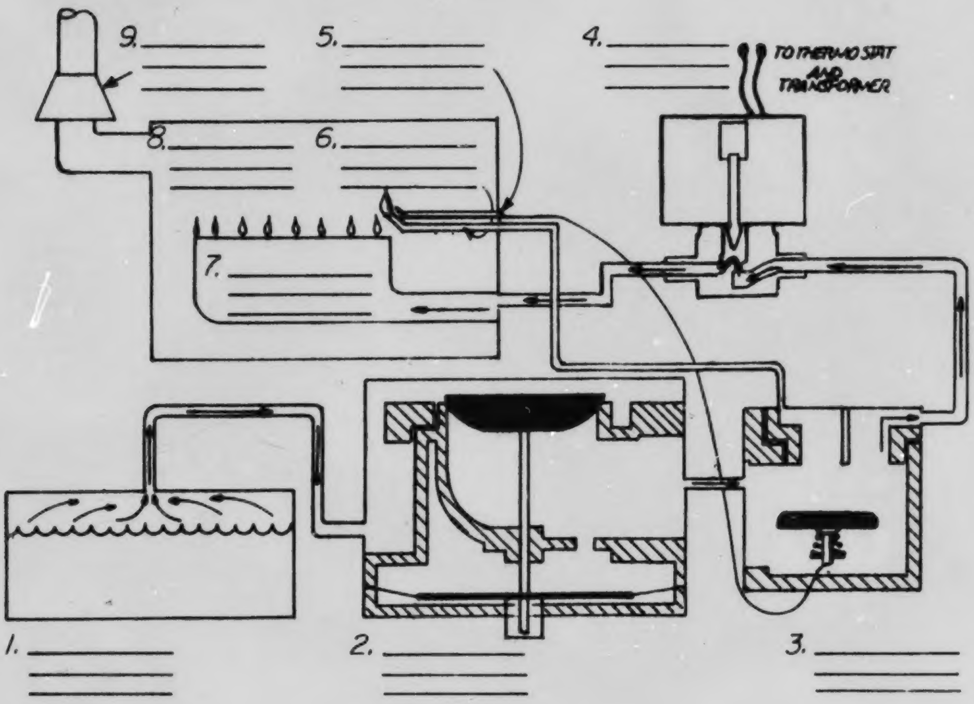

9.
5.
4.
TO THERMOSTAT AND TRANSFORMER
8.
6.
7.
1.
2.
3.

FIGURE B

The instructor will furnish tags to label each of the components on the gas fired heating unit pictured below in Figure C. You will be expected to describe the function of each part you label.

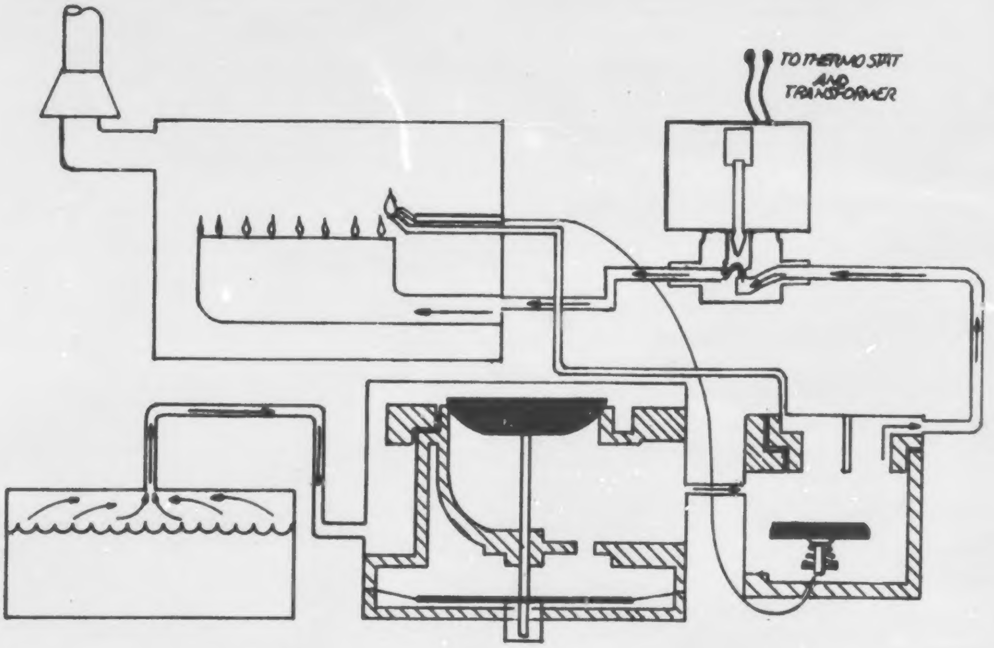

TO THERMOSTAT AND TRANSFORMER

FIGURE C

1. Upflow
2. Downflow
3. Horizontal
4. Low-Boy

In addition to these four types, several manufacturers produce many other specialized designs. The four basic designs, however, will cover most applications. Regardless of the type, all gas furnaces have two major sections; a blower compartment and a heat-exchanger section. The difference between the types is simply the arrangement of these two sections.

The blower compartment, as its name suggests, contains the blower, the blower motor and the filter. The return plenum is installed on this section of the furnace.

The heat exchanger section consists of the heat-exchanger, the burners, and the venting system. This compartment is the heart of the furnace and the supply plenum is installed on this section.

Although the furnace controls are a major part of all furnaces, they do not have their own separate compartments. They are usually located on the heat exchanger section, but on some types may be found in the blower compartment. Their locations may change with different manufacturers.

Even though controls are arranged differently on some furnaces, they are nearly always on the same side of the furnace and clustered together as much as possible. The same basic controls are used on most gas-fired furnaces.

The upflow (Figure D) is among the most common types of furnaces. It derives its name from characteristics of the upward air flow. The upflow furnace heat-exchanger is mounted on top of the blower compartment.

The controls are located at the front of the furnace near the center of the heat exchanger compartment. The draft-diverter and vent usually comes from the top of the furnace towards the front. Vents sometimes may come from the back. This arrangement keeps all heat-radiating surfaces above the fan motor which will insure cool motor operation.

The downflow furnace (Figure E) is used extensively for closet installed furnaces in single story structures. The conditioned air is delivered low in the room while unconditioned air is returned to the unit from higher in the room.

This prevents room air stratification because it is the reverse of natural convection of warm and cool air. A downflow, or counterflow, furnace looks similar to an upflow furnace. The downflow, however, has the blower compartment stacked on top of the heat exchanger. This design, like the upflow, keeps the lower motor cool. The controls are mounted on the front of the furnace, somewhat lower than is found on the upflow.

The vent comes from the top of the heat-exchanger which is located near the center of the furnace. It usually runs in front of the blower compartment.

In areas where crawl-space construction is used horizontal furnaces (See Figure F) are very common. Because of their low height and horizontal air-flow, they are ideal for crawl space and attic installations. The blower compartment and heat exchanger section usually faces the front of the unit. As in all furnace designs, the blower is located where the coolest operating temperatures may be found. The burners, draft diverter and vent may be located on either side of the furnace, depending on the application. The controls are normally located on the opposite side of the draft diverter and vented because of both space and temperature considerations.

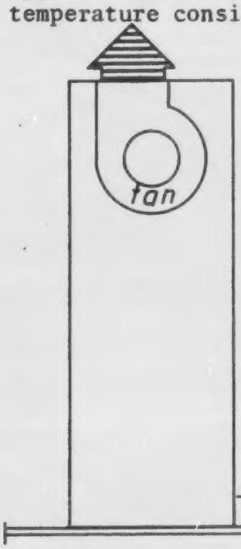


FIGURE D

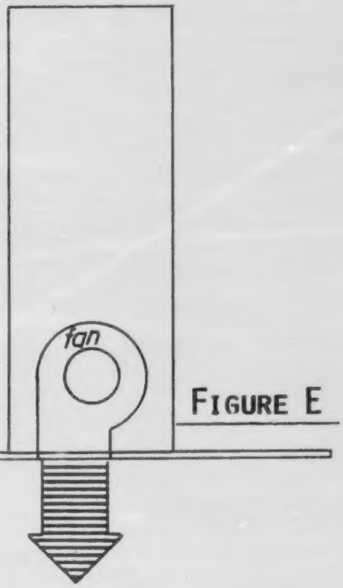
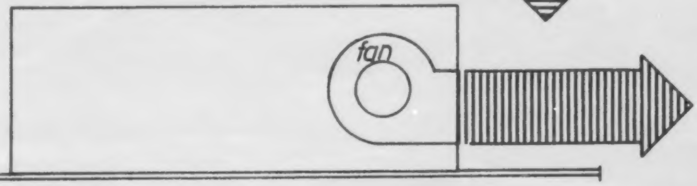


FIGURE E

FIGURE F



Low-boy furnaces are installed when their is little overhead room and a vertical air flow is required. Basically low-boy furnaces have the heat exchanger section and blower compartment side by side, rather than stacked. This reduces their height and still allows for a vertical air discharge. The two compartments may be placed either side by side or front to back.

Assignment Sheet HE-05b

Identify the types of furances listed in Column A by writing the serial numbers of furnaces located in the shop in Column B.

A	B
Lowboy	____________
Horizontal	____________
Down Flow	____________
Up Flow	____________

Job Sheet HE-05b

Identify the furnace type of five heating units in the lab. Record all information on this sheet in the space provided.

TYPE OF FURNACE	SERIAL NUMBER
1. ________________	____________
2. ________________	____________
3. ________________	____________
4. ________________	____________
5. ________________	____________

MAJOR BLOCK Heating **NAME** ____________

TASK Gas Heating Systems

UNIT Checking Gas Sources **TIME (est.)** ________ **(act.)** ________

UNIT NO HE-06

OBJECTIVE(S)

Check gas sources and determine rate of consumption.

START → W-1 W-2 C-1 W-3 A-1 W-4 C-2
W-5 W-6 C-3 L-1 C-4 L-2 C-5

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-06a	**A-1**	Slide Set HE-06a
W-2	Assignment Sheet HE-06a	**A-2**	
W-3	Text Assignment HE-06a	**A-3**	
W-4	Assignment Sheet HE-06b	**A-4**	
W-5	Information Sheet HE-06b	**A-5**	
W-6	Assignment Sheet HE-06c	**A-6**	
W-7		**A-7**	
LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-06a	**C-1**	Instructor Check
L-2		**C-2**	Instructor Check
L-3		**C-3**	Instructor Check
L-4		**C-4**	Instructor Check
L-5		**C-5**	Instructor Check
L-6		**C-6**	
L-7		**C-7**	
L-8		**C-8**	
L-9		**C-9**	

One of the most frequently ignored and often deceiving problems that can arise with a gas appliance is simply the source of gas.

Without proper gas pressure, no appliance will operate correctly. Most confusion is due to the service technician's reluctance to accept the fact that problems may exist somewhere other than in the equipment. A basic knowledge of how gas is supplied to the consumer can save many headaches and frustrations.

The basic measurement used to check out the gas source, is by determining the vapor pressure present at the source. This pressure is slight and is measured in inches of water column. A manometer is most often used for this purpose. Two basic designs are the U-tube and inclined manometers. The U-tube is simply a U-shaped tube filled with liquid and calibrated in inches on both sides. Some types are filled with colored water and calibrated in true inches while others in the interest of size, contain an oil fluid which is approximately twice as heavy as water. This permits the instrument to be half its normal size. An incline manometer is a straight tube with wells at each end for overflow. It is used for extremely low pressures. Some dial type guages are also used, however, they are not as accurate.

The two types of gas systems are natural and L.P. gas. Natural gas systems are by far the most common. Source problems are also unusual but do occur frequently enough to warrant some knowledge of their use. While most residential appliances operate at pressures between 3" to 3.5" W.C., most delivery pressures fall in a range between 5" and 12" W.C., 6" W.C. being the most common. If low gas pressure is suspected, take a reading with the unit off and carefully take the same reading with the unit on. A severe drop in pressure may indicate low gas pressure from the meter. The next check point should be directly after the meter. If the meter checks out, the problem probably belongs to the utility company. If, however, the operating and stagnant pressures are correct at the meter, but not at the unit, the problem is in the gas piping system and belongs to the service technician. When this occurs inspect the system for gas leaks and other piping system problems.

Assuming that a problem exists at the meter there are four possible answers. The meter may be undersized for the unit which can be determined by calling the gas company and checking its capacity against the total input of all the appliances. The meter may be faulty, for which the gas company has the responsibility. There may be a fault in the gas line to the meter or a low pressure situation may exist in the immediate service area. In any event the gas utility should be called. They can help to determine the cause and are the only people with the authority to correct the problem. Do not over react. Before calling the utility company, be sure that the problem is not the responsibility of the service technician.

L.P. Systems offer a few different problems. Most of these are due to the fact that L.P. gas delivery is desirable. As has already been mentioned, liquid petroleum is delivered and stored in liquid form under high pressure. This liquid must vaporize before it can be used as a gaseous fuel.

An L.P. tank which contains no liquid has a very low vapor pressure and is, for all practical purposes, empty. Also, a tank that is 100% full has a low vapor pressure because it contains no vapor. It may as well be empty. A tank which is 100% full of liquid is also dangerous. Since there is no room for expansion of the liquid, ruptured tanks or damaged equipment may result when the L.P. tank is overfilled. Even with the absence of vapor pressure, the liquid exerts a high pressure as it attempts to expand when its temperature rises. This high liquid pressure is useless for the appliance and is extremely dangerous to the tank and accessories.

Percentage liquid fill is the percent of the tank filled with liquid. It can be checked easily. Most non-portable L.P. storage tanks have percentage-fill gages. A gage reading of 80 indicates that the tank is 80% full of liquid. The tank must be above 0" and below 85% full for appliances to operate correctly and safely from it.

Much has been said about vaporizing liquid petroleum. For this to occur, heat must be available inside the tank. The surface of the tank which is exposed to the liquid in the tank provides the necessary heat. The surface is referred to as the "welted surfaced." The volume of gas which may be drawn from the tank is limited by its welted surface. For example, a 100 pound cylinder can vaporize a maximum of 113,000 per hour of propane gas at 0°F. If a tank this size was supplying a furnace with an input of 200,000 BTU/hr., very low gas pressure would result. Even if the storage tank has enough propane to operate the furnace for a month, the furnace would not operate correctly because of the low gas pressure. In short, a tank can be too small for a particular job. This possibility should be checked carefully before new appliances are added on line to an existing L.P. tank. An operable rule of thumb for determining tank capacity on propane applications is:

$$D \times L \times (F + 40) = BTU$$

D = Diameter of the tank in inches

L = Length of tank in inches

F = Percentage of tank filled

While this is not accurate enough to design tank installations, it should help in recognizing tanks which could possibly be marginal in size.

In the case of the 100 lb. propane tank which was inadequate at 0°F, a key contributing factor to the tank's performance was the temperature. The same tank can produce a maximum of 300,000 BTU per hour at 70°F. Since the air temperature supplies the heat for the tank, the higher the temperature, the more liquid which may be vaporized.

In the case of butane, it is possible to have a good percentage fill and a properly sized tank, but still have low vapor pressure. Butane's boiling point is 32°F. A storage tank which is at or below this temperature will exhibit low vapor pressure. All L.P. tanks should have a pressure gauge which indicates the tank vapor pressure. A tank pressure which does not remain significantly above the system's operating pressure will not provide enough pressure to move the fuel from the tank to the appliance.

The pressure inside an L.P. tank may reach vapor pressures of 200 PSIG under normal operating conditions. Obviously, since most L.P. appliances operate at 11 W.C., these high pressures must be regulated down to a usable pressure. Most systems use one regulator at the tank which provides 11" W.C. to all appliances. In the case of several appliances, cold temperatures, or large mass flow raters, several types of regulators must be used. The one on the tank reduces the pressure to around 15" W.C. while a second regulator on each appliance regulates the pressure to 11" W.C. This system is often called double regulation. A system with a malfunctioning regulator or an improperly applied regulator can exhibit low gas pressure.

Some L.P. tanks utilize a device called an excess flow valve. This valve shuts down the flow of gas completely when it exceeds a preset limit. If a system is designed to use a maximum of fifty cubic feet of gas per hour, the excess flow valve would probably shut the flow of gas off at seventy-five cubic feet per hour. Should a large leak develop, the excessive flow of gas would cause the valve to close and shut off the entire system. This protects against large quantities of gas from escaping but will not prevent small leaks from creating potential hazards.

While percentage fill, welted surface, tank pressure, regulators and excess flow valves are usually not the direct responsibility of the heating contractor, a basic knowledge of L.P. delivery systems is of vital importance in locating a source problem on an L.P. gas system.

Again, the first place to take a reading is at the unit. Then take a reading after the regulator on the tank. Do not take a W.C. gage reading before the regulator because tank pressures are often between 100 and 200 psi. If low pressure exists past the regulator, check for the following items:

a. Does the tank indicator show a sufficient amount of liquid?
b. If the temperature sufficiently above the boiling temperature of the gas?

c. Is the regulator adjusted for 11"-12" W.C.?
d. Is the tank large enough for the appliances which it serves?
e. Are the tank and connections in good shape?
f. Does the system need double regulation?
g. Are the regulator and excess flow valves operating correctly?

One of these items could be the problem. As always, look for the most obvious problem first.

In the case of L.P., source corrections may sometimes be made by the heating contractor. Some customers own their tank and all related equipment while others merely rent them from the gas company. Leaks should be repaired immediately if possible regardless of tank ownership. Replacement of regulators, valves, or gages should be maintained by the utility if the tank is company owned. The customer may request that the service technician perform the work if it is needed. In any case, however, courtesy should always be extended to the customer and to the gas company involved.

Circle T if the entire statement is true and F if any part of statement is false. If the statement is false, correct it.

T F 1. Most L.P. appliances do not have their own regulator.

T F 2. Most natural gas appliances operate at 3.5" W.C. gas pressure.

T F 3. Excess flow valves shut off the gas supply completely when the pre-set flow is exceeded.

T F 4. Wetted surface is the total surface area of an L.P. storage tank.

T F 5. A double regulator is used in a double regulation system.

T F 6. The pressure in the gas line of a natural gas system is usually around 6" W.C.

Assignment Sheet HE-06b

Read the following diagrams and fill in the inches water column.

INCHES WATER COLUMN

1. Dial set to 2.5 ______________
2. Slack tube up 2.5, down 2.5 ______________
3. Bacharach up 3 ______________
4. Slack tube up 6 ______________
5. Slack tube up 1.75, down 1.75 ______________

Draw in the appropriate fluid level.

6. 3.5 W.C.

7. 11" W.C.

8. 5.75" W.C.

9. 2" W.C.

10. 10" W.C.

Reading Gas Meters

There are circumstances, such as checking for leaks or determining gas input, when reading or clocking a meter will be useful. These are all simple procedures.

As shown in Figure A, most meters have several dials. Each dial measures a different volume of gas. Adjacent dials turn in opposite directions as the calibrations indicate.

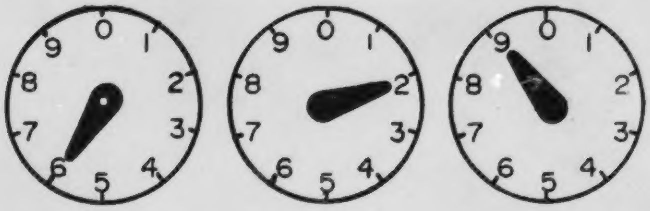


FIGURE A

To read the meter, read from left to right. When the dial is between two numbers use the smallest of the numbers. In the diagram, the first dial from the left indicates that 600 thousand cubic feet of gas have passed through the meter. The next dial indicates that an additional 20 thousand cubic feet have been used and the last dial shows that 9 thousand cubic feet were used. Therefore, the reading is 629, or 629,000 cubic feet of gas. This would be billed at 6.29 therms.

Usually, these dials would be useful only for recording large quantities of gas consumed over extended periods of time. The two smaller dials are used for "clocking" a meter. Clocking a meter is the process by which a mechanic can determine an appliances actual gas input. To determine an appliances BTU input per hour:

(A) Turn off all appliances except the one being checked.
(B) Count the number of turns of either of the small dials for a specific period of time.
(C) Determine the cubic feet used by: number of turns X the dial value.
(D) Multiply the consumption by the ratio of 60 minutes time elapsed.
(E) Multiply this cubic feet per hour by the heat content of the gas.

For example:

The half foot dial revolves thirty times in five minutes. The consumption would be 30 x ½ = 15 cubic feet. The comsumption per hour would be 15 x $\frac{60}{5}$ = 180 cubic feet per hour. The BTU input would be 180 CFH x 1000 $\frac{BTU}{CF}$ = 180,000 BTU per hour input.

The time period and dial depends on the consumption of the system being checked. A large boiler might spin the ½ foot dial too fast to easily count. However, a gas range might turn the two foot dial too slowly to get an accurate reading. The longer the sampling period, the more accurate results are likely to be. Production is important so as little time as possible should be spent on checking the meter to avoid wasted man hours. Usually a one or two minute period will give usable results.

The half foot dial may also be used to test for leaks. With all appliances and pilot lights off, the dial should remain stationary. If it continues to move after all appliances have been shut down, a leak is apparent in in the system. (See Figure B).

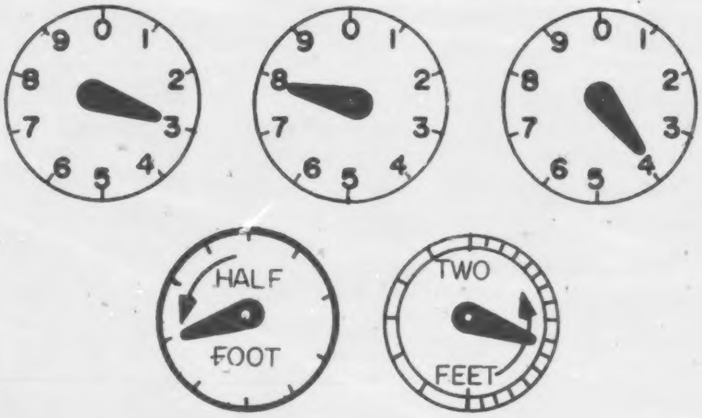
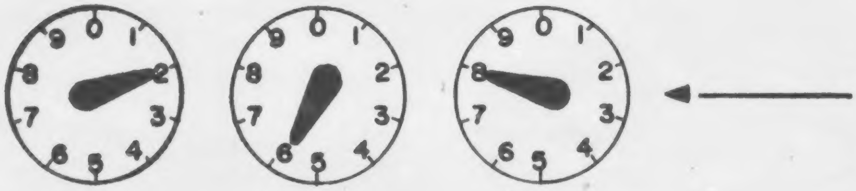
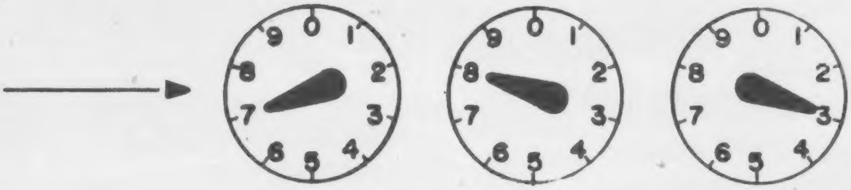


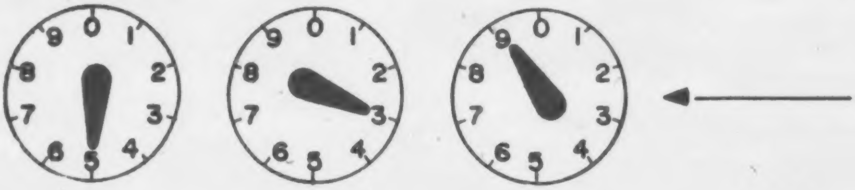
FIGURE B

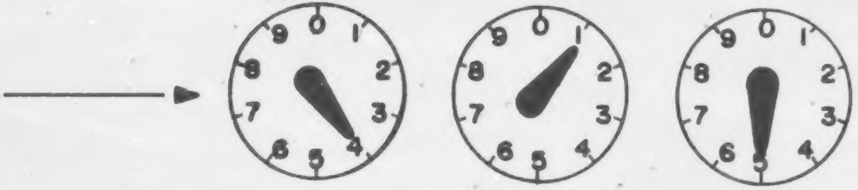
Assignment Sheet HE-06c

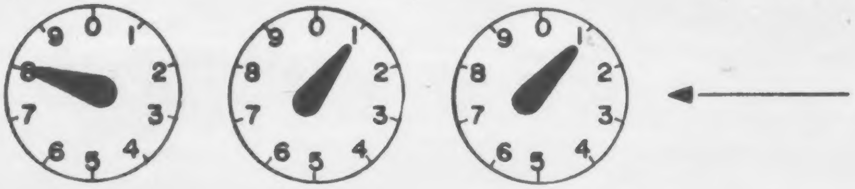
Write the meter reading beside the diagram.











The instructor will assign a gas meter to determine the consumption per hour. Use the form below.

________________	x	________________	x	60
number of turns		value of dial		time clocked

Read the instructions for the instrument(s) assigned to check the gas sources. These will be assigned by the instructor. Record the necessary information in the chart below.

	UNIT 1	UNIT 2
1. At source, unit off	________	________
2. At source, unit on	________	________
3. At unit, unit off	________	________
4. At unit, unit on	________	________

MAJOR BLOCK Heating **NAME** ____

TASK Gas Heating Systems

UNIT Gas Piping Principles **TIME (est.)** ____ **(act.)** ____

UNIT NO HE-07

OBJECTIVE(S)

Calculate and install gas piping for gas heating systems.

START → W-1 → W-2 → C-1 → L-1 → C-2 → A-1 → L-2 → C-3

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-07a
W-2 Assignment Sheet HE-07a
W-3
W-4
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-07a
L-2 Job Sheet HE-07b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-07a
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4
C-5
C-6
C-7
C-8
C-9

The National Fire Protection Association is the most widely recognized authority in fire prevention. It is an independent organization and has no legal code-enforcing powers. However, most government fire codes come directly from NFPA's bulletins which are the end product of much research into the science of fire prevention. The sizing procedures set forth here are not drawn from any governmental code, but rather from the National Fire Protection Association's Bulletin on the "Installation of Gas Appliances and Gas Piping."

Five factors used to determine gas piping size are:

a. allowable pressure loss from the source to the unit.
b. maximum consumption to be provided.
c. length of pipe and fittings.
d. specific gravity of the gas.
e. diversity factor.

The maximum allowable pressure loss is the difference in the gas pressure between the source and the appliance. This is limited by the difference between the minimum source pressure available and the minimum pressure needed at the appliance. For instance, if the gas pressure at the source is 3.5" W.C. and the unit requires at least 3" W.C. to operate, the maximum allowable loss could be no more than ½" W.C. On the other hand, if the minimum source pressure was 7" W.C. and the unit operated at 3½" W.C., the maximum allowable pressure loss would be 3.5" W.C. Generally, gas piping is sized for a maximum pressure loss of between 0.35" W.C. and 0.5" W.C.

The maximum consumption of the appliance refers to the maximum cubic feet of gas per hour that the unit would use. This is easily found by dividing the unit's rated input in BTU's per hour by the BTU content of the gas. This is approximately 1000 BTU/ft^3 for natural gas, 2500 BTU/ft^3 for propane, and 3200 BTU/ft^3 for butane. For the exact BTU content of the gas in a specific area, contact the gas supplier.

The piping length is simply the actual length of pipe between the source and the appliance plus the equivalent feet of fittings. For the purpose of using gas piping sizing tables, no additional allowance needs to be made for a normal amount of fittings. To use table HE-07a,

A. Determine the length of the piping to the appliance which is the greatest distance from the source.
B. Using that length, find a capacity equal to or greater than the capacity to be delivered by a particular section of pipe. The pipe size recommenced is on the left-hand column directly across from the listed capacity.

Example:

Using Figure A and Figure B, the farthest run is 60' to the water heater. This is the length used to determine the pipe size. Under the 60' column, find the minimum capacity that is equal to or greater than 30 CFH. It is 35 CFH with ½" pipe. Therefore, the branch to the water heater is ½" pipe.

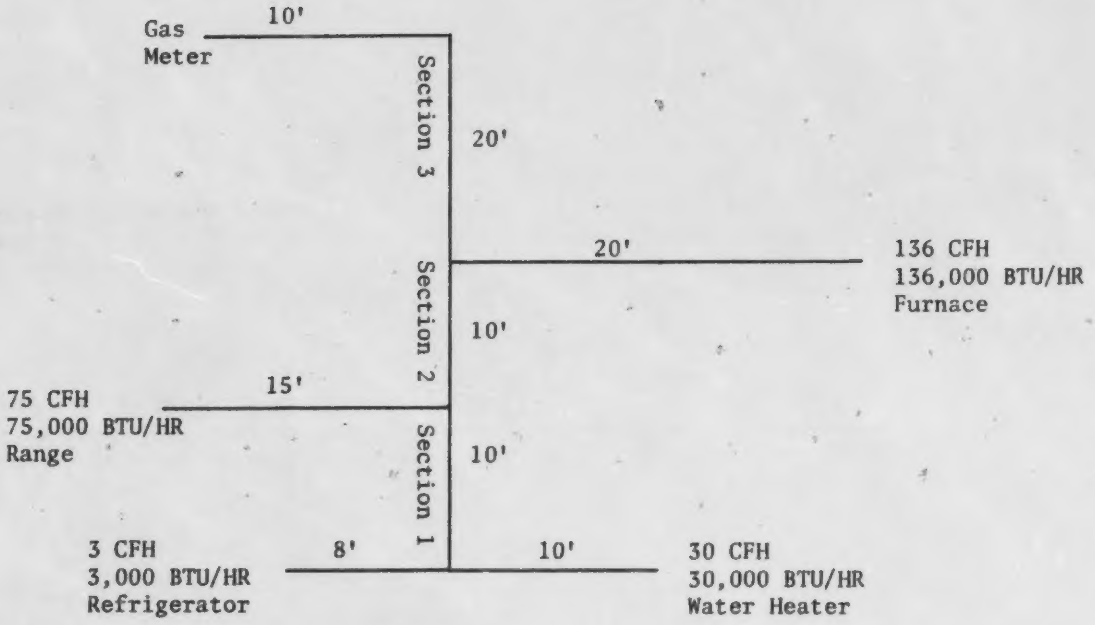
FIGURE A

MAXIMUM CAPACITY OF PIPE IN CUBIC FEET OF GAS PER HOUR

(Based upon a pressure drop of 0.5 inch water column and 0.6 specific gravity gas. For other pressure drops, multiply by 0.5, where is the pressure drop, inches water column.)

Nominal Iron pipe size, inches	Length in Feet													
	10	20	30	40	50	60	70	80	90	100	125	150	175	200
1/2	175	120	97	82	73	66	61	57	53	50	44	40	37	35
3/4	360	250	200	170	151	138	125	118	110	103	93	84	77	72
1	680	465	375	320	285	260	240	220	205	195	175	160	145	135
1 1/4	1,400	950	770	660	580	530	490	460	430	400	360	325	300	280
1 1/2	2,100	1,460	1,180	990	900	810	750	690	650	620	550	500	460	430
2	3,950	2,750	2,200	1,900	1,680	1,520	1,400	1,300	1,220	1,150	1,020	950	850	800
2 1/2	6,300	4,350	3,520	3,000	2,650	2,400	2,250	2,050	1,950	1,850	1,650	1,500	1,370	1,280
3	11,000	7,700	6,250	5,300	4,750	4,300	3,900	3,700	3,450	3,250	2,950	2,650	2,450	2,280
4	23,000	15,800	12,800	10,900	9,700	8,800	8,100	7,500	7,200	6,700	6,000	5,500	5,000	4,600

FIGURE B


Gas
Meter
10'
Section 3
20'
20'
136 CFH
136,000 BTU/HR
Furnace
Section 2
10'
75 CFH
75,000 BTU/HR
Range
15'
Section 1
10'
3 CFH
3,000 BTU/HR
Refrigerator
8'
10'
30 CFH
30,000 BTU/HR
Water Heater

Next, look for the minimum acceptable capacity for the refrigerator. It is also 35 CFH at ½" pipe. Section 1 must be sized to carry both the water heater and the refrigerator. This would be 33 CFH. Again, ½" pipe will carry it. The range requires 75 CFH. 3/4" pipe will carry up to 138 CFH so 3/4" pipe is used for the range. Section 2 must carry the range, the water heater and the refrigerator. This totals 107 CFH, still serviceable ly 3/4" pipe. The furance requires 136 CFH, again, 3/4" pipe. Section 3, however, must be sized to handle all the appliances at 244 CFH. This requires 1" pipe since it will carry up to 260 CFH.

This sizing is only valid for a gas with a specific gravity of 0.6 using rigid pipe and with a design pressure drop of 0.5" W.C. A change in any of these factors could affect the sizing of the pipe.

The specific gravity of the gas changes the size of pipe needed to deliver a set quantity of gas at a set pressure. The heavier the gas, the harder it is to move. Therefore, the heavier the gas, the longer the piping needs to be. A comparison of charts on Figure C and Figure A will show the difference the specific gravity can make in a pipe's capacity. Make certain that the sizing chart you use is for the specific gravity of the gas to be handled. The chart on Figure D gives factors to be used to connect capacities in chart to capacities for different specific gravity gases.

Specific Gravity	Multiplier	Specific Gravity	Multiplier
0.35	1.31	1.00	0.78
0.40	1.23	1.10	0.74
0.45	1.16	1.20	0.71
0.50	1.10	1.30	0.68
0.55	1.04	1.40	0.66
0.60	1.00	1.50	0.63
0.65	0.96	1.60	0.61
0.70	0.93	1.70	0.59
0.75	0.90	1.80	0.58
0.80	0.87	1.90	0.56
0.85	0.84	2.00	0.55
0.90	0.82	2.10	0.54

FIGURE C

The diversity factor refers to the ratio of maximum probable demand to the maximum possible demand. In other words, how much gas is likely to be used versus how much could be used. Take the case of a house with a separate gas furnace (rated at 100,000 input) and a gas air conditioner rated at 50,000 BTU/hr input. Since both would logically never need to be on simultaneously, the maximum probable demand would be the higher demand of the two (the furnace at 100,000 BTU/hr input). However, if both were turned on simultaneously, they would give a maximum possible demand of 150,000 BTU/hr. In this case, the diversity factor would be $\frac{100,000}{150,000}$ or $\frac{2}{3}$. (.6T) This factor means that instead of sizing the system for 150,000 BTU/hr it can be sized at $\frac{2}{3}$ that demand, or 100,000 BTU per hour. This becomes a reality in apartment complexes or other installations where the highest possible demand is not likely to occur. To apply the diversity factor, simply multiply it times the maximum possible demand of the system to find the comsumption figures to use in sizing the pipe.

To size gas pipe, determine the specific gravity of the gas, the length of the run, and the consumption to be provided. Then, using a sizing chart, look up the size pipe which will carry the required volume of gas which is the length of the pipe at the maximum allowable pressure loss.

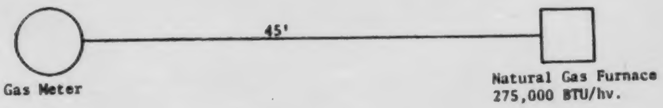
FIGURE D

Capacity of Semi-Rigid Tubing of Different Outside Diameters and Lengths in Thousands of BTU Per Hour of Undiluted Liquefied Petroleum Gases at a Pressure Drop of 0.50 Inch Water Column

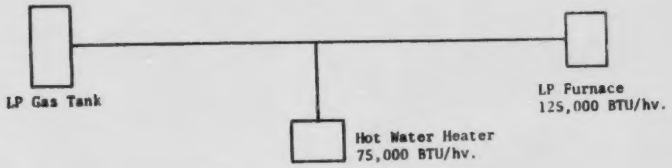
Outside diameter (inches)	Length of tubing (feet)									
	10	20	30	40	50	60	70	80	90	100
3/8	39	26	21	19						
1/2	92	62	50	41	37	35	31	29	27	26
5/8	199	131	107	90	79	72	67	62	59	55
3/4	329	216	181	145	131	121	112	104	95	90
7/8	501	346	277	233	198	187	164	155	614	138

Size the following hypothetical systems according to the 5 NFPA sizing factors. Use the charts in Information Sheet HE-07a.

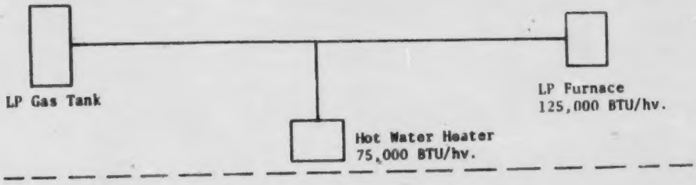
Plan E-1 Calculate gas piping sizes:


45'
Gas Meter
Natural Gas Furnace
275,000 BTU/hv.

Plan E-2 Calculate gas piping sizes:


LP Gas Tank
LP Furnace
125,000 BTU/hv.
Hot Water Heater
75,000 BTU/hv.

Plan E-3 Calculate gas systems size (LP and natural gas):


LP Gas Tank
LP Furnace
125,000 BTU/hv.
Hot Water Heater
75,000 BTU/hv.

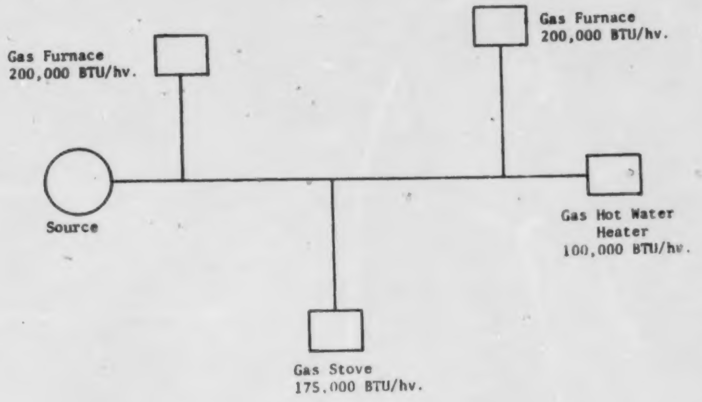

Gas Furnace
200,000 BTU/hv.
Gas Furnace
200,000 BTU/hv.
Source
Gas Hot Water
Heater
100,000 BTU/hv.
Gas Stove
175,000 BTU/hv.

FIGURE E

Job Sheet HE-07a

Size a gas piping system for a unit assigned by the instructor. Be sure and cover all of the five size factors. Record the necessary information in the chart below.

Specific Gravity ____________________

Allowable Pressure Drop ____________________

Maximum Consumption ____________________

Length of Run ____________________

Diversity Factor ____________________

Job Sheet HE-07b

Select the appropriate materials and tools to install the piping system sized in Job Sheet HE-04a. Install the system according to the NFPA "Gas Appliances and Gas Piping" Bulletin. Record all information in the chart below.

Data Chart

Type of Gas: Heat Content ____________
Specific Gravity ____________
Chemical Formula ____________

Length of run ________________________

Consumption ________________________

Diversity Factor ________________________

Adjusted Consumption ________________________

Allowable Pressure Drop ________________________

Actual Pressure Drop ________________________

MAJOR BLOCK Heating **NAME** ____________

TASK Gas Heating Systems

UNIT Adjusting Regulators **TIME (est.)** ________ **(act.)** ______

UNIT NO. HE-08

OBJECTIVE(S) Install and adjust gas pressure regulator(s)

START ➔ A-1 W-1 L-1 C-1 W-2 W-3 W-4 L-2 C-2

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Information Sheet HE-08a	A-1	Slide Set HE-08a
W-2	Information Sheet HE-08b	A-2	
W-3	Assignment Sheet HE-08a	A-3	
W-4	Information Sheet HE-08c	A-4	
W-5		A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Job Sheet HE-08a	C-1	Instructor Check
L-2	Job Sheet HE-08b	C-2	Instructor Check
L-3		C-3	
L-4		C-4	
L-5		C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

Procedures for disassembling and reassembling a gas pressure regulator. Use a parts box to store all gas regulator parts.

1. Always read the instructions.

2. Obtain a gas pressure regulator and a parts box from the instructor.

3. Find a clean, flat work space with approximately 3 square feet of area.

Gas Regulator

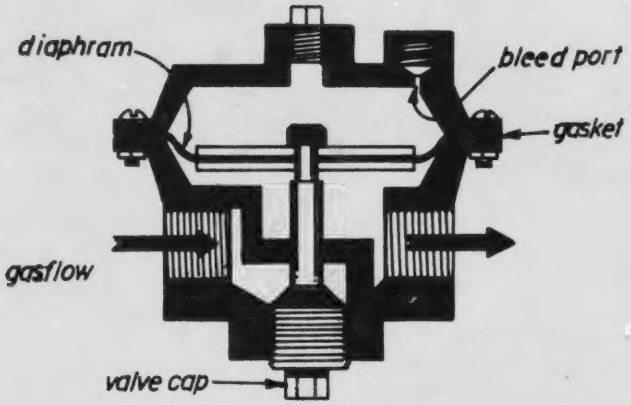


FIGURE A

4. Locate the plug on the bottom of the regulator. To remove, use a wrench to turn it counterclockwise. Place it in the parts box.

5. Locate the plunger. Gently push on the plunger until it stops. While holding the vent hole to one ear, release the plunger quickly. A hissing sound should be heard as air rushes into the upper diaphragm chamber through the vent restrictor hole. If a hissing sound is not heard, the regulator may have a plugged vent or a ruptured diaphragm. Again, depress the plunger gently until it is at full stop position. Seal both the pressure adjustment cylinder and the vent hole with duct-tape so they will be air-tight. Release the plunger. It should not move. If it moves, the diaphragm is ruptured, the gasket leaks, or the tape is not air-tight. If the plunger moved, check the tape and try again. If no movement is apparent, remove the tape from the vent hole and observe the plunger. The plunger should return. If not, the vent hole is stopped up.

6. Locate the pressure adjustment cap. Use the proper tool, whether a slotted screwdriver or a wrench, to remove the cap. Turn the cap clockwise. Place it in the parts box.

7. The pressure adjustment screw should now be seen. It is located inside the adjustment cylinder beneath the pressure adjustment cap. Use a screwdriver to turn it counterclockwise until it comes completely out of the cylinder. Be careful not to let the spring fall out. Place the adjustment screw in the parts box.

8. Carefully remove the spring and place it in the parts box. Use a grease pencil or a felt marker and put a mark across the two gasket surfaces to indicate the correct position of the top and bottom halves.

9. Loosen all the screws holding the two chambers of the regulator together by turning the screws counterclockwise. When all are loosened, remove them and place them in the parts box. The regulator should now separate into two parts. If the halves do not easily separate, tap the gasket surface lightly with a soft mallet. Do not use a hard metal hammer. It could break the regulator body. Do not force a screwdriver between the two surfaces or pry with a knife. This could damage the gasket and the diaphragm.

10. After removing the top, hold the vent hole close to a light and look through it. A screen can be seen which acts as a filter to keep foreign particles out of the upper diaphragm chamber. Also notice the condition of the gasket. It should be smooth and free of cuts and abrasions. Place the regulator top in the parts box.

11. Now the diaphragm, the upper stop disc, the threaded portion of the plunger, and the retaining nut and washer can be seen. Notice that the lip on the stop disc is turned upward. Loosen the retaining nut by turning it counter-clockwise with a wrench while holding the plunger stationary with a screwdriver. Do not turn the plunger because this tends to rotate the stop discs and may tear the diaphragm. Place the retaining nut and washer in the parts box.

12. While grasping the upturned lip of the upper stop disc, remove the diaphragm assembly. The diaphragm, and the upper and lower stop discs should all come out as a unit. Do not attempt to separate them because they often are glued together. Separating them could tear the diaphragm. Inspect the diaphragm for tears and holes. Place the diaphragm assembly in the parts box.

13. Notice that the lip on the remaining disc is turned down. Remove it and place it in the parts box. Remove the plunger retaining clip and place it in the parts box. Remove the sealing washer on the plunger and inspect it for wear. Place it and the plunger into the parts box.

14. The regulator is now completely disassembled. Ask the instructor to examine the disassembled regulator.

15. Hold the plunger up through the bottom of the regulator body and snap the retaining clip onto the plunger shaft. Replace the rubber plunger sealing washer. Lay the small deflecting disc, ridge down, on top of the plunger.

16. Place the diaphragm assembly over the bottom half of the regulator. Be careful to put the lower stop disc down. Make sure the holes in the diaphragm match the locating pegs and the screw holes.

17. Place the retaining washer over the upper stop disc. While holding the plunger stationary with a screwdriver, tighten the retaining nut over the threaded portion of the plunger by turning the nut clockwise and tighten with a wrench. Do not overtighten; very little torque is required to hold the plunger to the diaphragm.

18. Align the holes in the top of the regulator with the locating pegs. Be sure to match up the mark made earlier on the top and bottom of the regulator. Tighten the screws fingertight by turning them clockwise. After all the screws are fingertight, tighten them 1/4 to 1/2 turns with a screwdriver. Tighten diagonally opposed corners first. Retighten all screws to approximately the same torque (very slight).

19. Replace the spring and run the adjusting screw about halfway down the cylinder by turning it clockwise with a screwdriver.

20. Gently depress the plunger until it stops. Tape over the pressure adjustment cylinder and the vent hole. Observe the plunger; it should not move. If it moves now but did not move in Step 6, the gasket leaks. If this is the case, disassemble the top and bottom halves, and repeat Steps 19 through 20.

21. Run the bottom plug into the bottom of the regulator by turning it clockwise. Tighten snugly with a wrench. Replace the adjustment cap and tighten snugly by turning it clockwise.

22. Clean up the work area and show the instructor the reassembled regulator.

Job Sheet HE-08a

Following the instructions in Information Sheet HE-08a, disassemble and reassemble a gas pressure regulator. Record the necessary information about the assigned regulator in the chart below.

Type of Gas ____________________

Maximum Inlet Pressure ____________________

Maximum Outlet Pressure ____________________

Diaphragm Condition (Ruptured or O.K.) ____________________

Plunger and Plunger Seat Condition ____________________

Gasket Condition ____________________

Regular Capacity ____________________

Regular Condition ____________________

Sizing Regulators

When selecting a pressure regulator for a system, three factors need to be considered:

A. The type of gas used.
B. The operating pressures needed.
C. The volume of gas needed.

These system characteristics should match regulator characteristics or poor regulator performance may result.

Most regulators are designed for a specific gas. Use a regulator designed for the type of gas the unit requires. Natural gas and L.P. gas which have different chemical make-ups, react differently with certain materials. A gasket which can be used with natural gas, may dissolve when exposed to L.P. gas. To determine which type of gas a regulator is designed for, look on the regulator for the initials L.P. for liquid petroleum, or Nat. for natural gas.

Two different operating pressures must be considered when choosing a regulator. These are the pressure which is to be imposed on the high-pressure side of the regulator, and the regulated pressure needed on the low pressure side of the regulator.

The high pressure applied to the regulator must be smoothly balanced by the spring pressure on the opposite side of the diaphragm. Therefore, the strength of the pressure adjustment spring helps determine the range of pressure which may be applied to the regulator. All other factors being equal, two regulators could differ only in their range of applied operating pressure. If a regulator is to be installed on an L.P. tank which produces pressure of up to PSIG, it must be able to handle the applied operating pressure.

The regulated operating pressure is just as important as the applied operating pressure. The same regulator which must withstand an incoming pressure of 200 PSIG must be able to control the gas flow to an L.P. appliance at 11" W.C. A higher pressure would dangerously overfire the furnace, while a lower pressure would cause it to burn below capacity. When selecting a regulator for a particular application, the regulator outlet as well as inlet pressure must be considered.

After determining the type of gas the regulator must handle and the pressures which are required, the volume of gas to be handled must be determined. A regulator made to handle 500,000 BTU of gas per hour would naturally be larger than one made to handle 10,000 BTU per hour. Most regulators are sized in BTU per hour for the type of gas they handle. The rating of the regulator should be equal to or greater than the sum of the inputs of all the appliances connected to it.

A regulator sized to handle a 50,000 BTU/hr. furnace and a 30,000 BTU/hr. water heater should be rated at least 80,000 BTU/hr. A 100,000 BTU/hr. regulator would work fine. A 60,000 BTU/hr. regulator would be adequate when only one appliance was burning. However, if both furnace and water heater were turned on, a severe pressure drop would result because of the under-sized regulator.

To insure a properly sized regulator, determine the type of gas to be handled. Match the operating pressures to the system, and select a capacity equal to or greater than the total load. These three application factors are vital to the correct performance of a gas pressure regulator.

When large amounts of gas are used either several units are operated from one source or more precise pressure control is needed. Double regulation may be used. Double regulation is the practice of reducing the pressure at the source with one regulator, and then reducing it further at the unit with another regulator.

When gas moves from a high pressure to a low pressure, it expands and absorbs heat. When a large amount of gas is passed through a regulator, it may cool off the regulator to the point it freezes up. By using a second regulator, the pressure drop across the first regulator may be reduced. This reduces the gas expansion and then raises the regulator temperature. In this way, freeze-ups may be avoided.

When several units are operated off a single source, load variations may make a single regulator impractical. By installing a regulator at the source to regulate down to 7" W.C., and installing regulators on each unit to regulate down to 3.5" W.C., pressure changes with load differences are reduced. This is typically how natural gas systems are handled.

A third use of double regulation comes in supplying appliances which must have a critical fuel to air ratio. If the gas pressure has to be maintained at exactly 11" W.C., two regulators may be needed to control it. By regulating the pressure from the source to 15" W.C., and then at the unit to 11" W.C., pressure differences between the two regulators can be dampened.

Double regulation can cure problems that can not be solved otherwise. If the regulator on a system does not do an adequate job, but is sized correctly and in good shape, double regulation may be used. Two are better than one.

Select the regulator(s) required to supply the following systems from the following list of regulators. Specify their settings.

System #1
Natural gas, 12" main line pressure incoming, short gas lines.
1 - 80,000 BTU input furnace
1 - 20,000 BTU water heater

System #2
L.P. gas, outside propane tank, low ambient conditions.
1 - 150,000 BTU input boiler
1 - 10,000 BTU input stove
1 - 25,000 BTU input water heater

Types of Regulators

A. 30,000 BTU L.P. Regulator
--maximum inlet pressure 25" W.C.
--maximum outlet pressure 11" W.C.

B. 25,000 BTU natural regulator
--maximum inlet pressure 12" W.C.
--maximum outlet pressure 5" W.C.

C. 150,000 BTU natural gas
--maximum inlet pressure 5 PSIG
--maximum outlet pressure 7" W.C.

D. 100,000 BTU L.P. butane
--maximum inlet pressure 100 PSIG
--maximum outlet pressure 11" W.C.

E. 100,000 BTU natural gas
--maximum inlet pressure 20" W.C.
--maximum outlet pressure 7" W.C.

F. 15,000 BTU propane
--maximum inlet pressure 200 PSIG
--maximum outlet pressure 12" W.C.

____
____
____

G. 200,000 BTU propane
--maximum inlet pressure 200 PSIG
--maximum outlet pressure 12" W.C.

____
____
____

H. 80,000 BTU natural
--maximum inlet pressure 7" W.C.
--maximum outlet pressure 5" W.C.

____
____
____

Regulator Installation

Before any regulator can work properly, it must be installed correctly. The following is a list of general procedures for installing a regulator.

Procedures

1. Apply pipe dope to the threads of the pipe before screwing into the regulator. Leave the last two threads clean to avoid getting dope on the inside of the regulator.

2. Tighten the pipe with a pipe wrench, holding the regulator body with an open end wrench. Do not hold the regulator with either pliers or a pipe wrench. A pipe wrench may break or crack the regulator. Cracked regulator bodies are dangerous.

3. If the regulator is outside of the house, make sure the vent opening is down. This prevents debris from lodging in the vent hole and allows condensation to run out. Turning the vent hole down is not a bad practice even if the regulator is located inside.

4. If the regulator is inside, run a vent line from the vent either outside or to the combustion chamber. Most codes require outside venting on L.P. systems.

5. Check the regulator adjustment and adjust to the necessary pressure.

The instructor will assign a unit on which the gas pressure regulator should be adjusted. Determine the setting and make the adjustment. To adjust a gas pressure regulator, you will need:

1. a small crescent wrench,
2. a medium flat-tip screwdriver and
3. a water column gauge or manometer.

First, install the manometer or water column gauge on the burner manifold of the unit to be checked. Turn the unit on and observe the pressure reading. If it is incorrect (3" natural, 11.5 L.P.) servicing may be required. If the source is adequate and the gas line is unobstructed, the problem may be solved by adjusting the regulator.

To adjust the regulator, first, remove the adjustment cylinder cap. This should provide access to the adjustment screw. Turn the screw clockwise to increase the regulated pressure and counter-clockwise to decrease the regulated pressure. Be patient! Do not turn the adjustment screw more than ½ turn at a time. Check the pressure at the unit after each adjustment.

When the operating pressure is correct, show the instructor. Turn the unit off, replace all tools, and clean the work area.

UNIT #1 Serial Number ____________________

Inlet Pressure ____________________

Outlet Pressure ____________________

Type of Gas ____________________

Unit's Gas Input ____________________

Regulator Capacity ____________________

UNIT #2 Serial Number ____________________

Inlet Pressure ____________________

Outlet Pressure ____________________

Type of Gas ____________________

Unit's Gas Input ____________________

Regulator Capacity ____________________

MAJOR BLOCK Heating **NAME** ______

TASK Gas Heating System

UNIT Installing and Servicing Gas Valves **TIME (est.)** ______ **(act.)** ______

UNIT NO HE-09

OBJECTIVE(S)

Recognize and install gas valves.

START ➡ W-1 ▷ W-2 ▷ C-1 ▷ A-1 ▷ L-1 ▷ C-2 ▷ L-2 ▷ C-3 ▷

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-09a
W-2 Assignment Sheet HE-09a
W-3 ______
W-4 ______
W-5 ______
W-6 ______
W-7 ______

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-09a
L-2 Job Sheet HE-09b
L-3 ______
L-4 ______
L-5 ______
L-6 ______
L-7 ______
L-8 ______
L-9 ______

AUDIOVISUAL(S)

A-1 Slide Set HE-09a
A-2 ______
A-3 ______
A-4 ______
A-5 ______
A-6 ______
A-7 ______

CHECKPOINT(S)

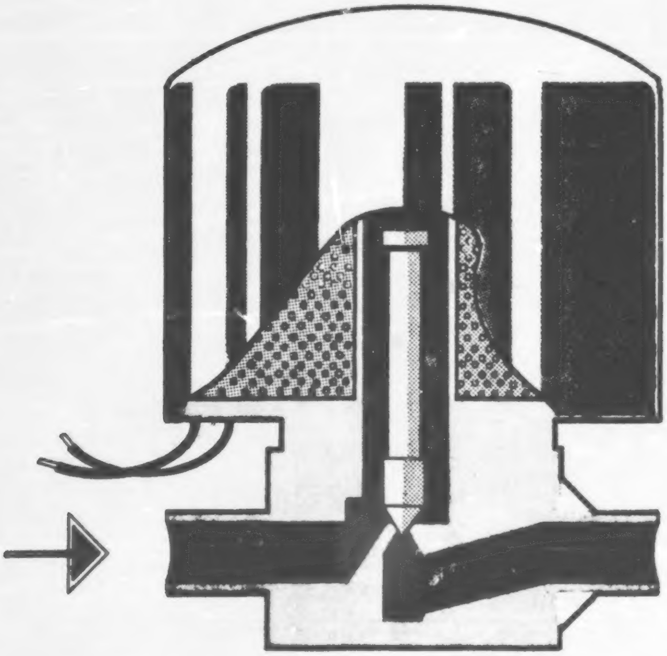
C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 ______
C-5 ______
C-6 ______
C-7 ______
C-8 ______
C-9 ______

Main gas valves are used to control the flow of gas to the burner. The valve breaks down to four main parts: the valve body, valve seat, valve disc, and the valve stem. Anytime the disc is lifted off the valve seat, gas will flow through the valve. Gas valves are classified by the type of power used to open and close them. There are four types of general gas valves:

1. Solenoid (direct acting)
2. Diaphram
   a. magnetic
   b. bimetal
3. Bimetal (direct acting)
4. Heat motor (direct acting)

The solenoid valve (Figure A) is an electrically operated stop valve. The solenoid valve used on most heating systems is normally closed if not electrically engaged. When power (usually 24v) is applied to the coil the valve opens and allows gas to flow to the burners.

Special features have been added to the valve to reduce noises as it opens and closes. Closing noises are softened through the use of rubber or plastic seats. When the coil is electrically engaged an extension spring lessens the speed of the valve as it opens and restricts noises which may have been produced. Also, some solenoids are oil filled to eliminate operating noises.



SOLENOID

FIGURE A

Figure B is an example of a solenoid operated diaphram valve in its normally closed position. The spring attached to the bleeder valve lever holds the valve against the bleed port opening at the top of the diaphram. As long as the bleeder valve remains in this position the pressure above and below the diaphram holds the main valve closed so that no gas can flow.

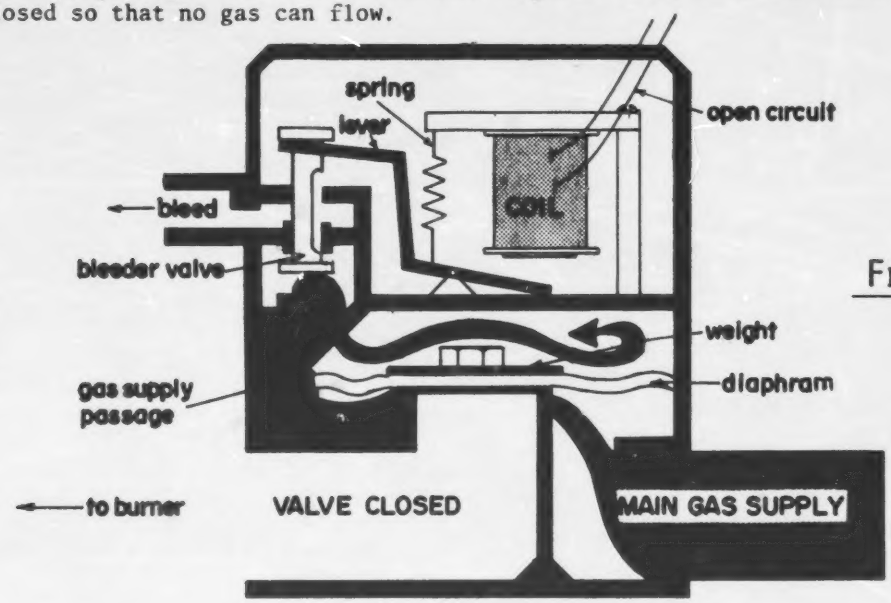

spring
lever
open circuit
COIL
bleed
bleeder valve
weight
diaphram
gas supply passage
to burner
VALVE CLOSED
MAIN GAS SUPPLY

FIGURE B

Figure C shows the diaphram after the coil is energized. The lever is magnetically pulled against the coil closing the gas supply passage and venting the gas pressure above the diaphram out through the bleed. Because the pressure below the diaphram is greater, the weight and disc are lifted off the seat allowing gas to flow through the valve to the burners. The gas that escaped through the bleed opening is routed to the vicinity of the pilot flame and is burned off as the main burner lights.

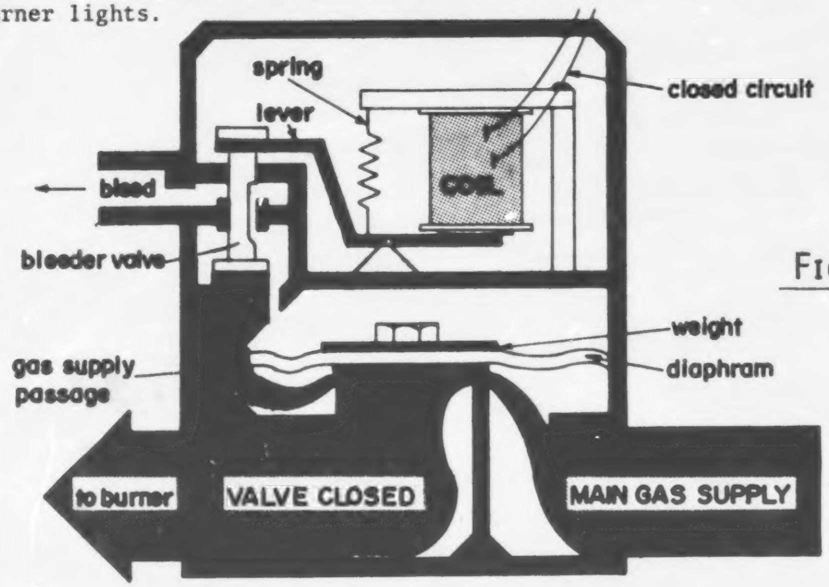

spring
lever
closed circuit
COIL
bleed
bleeder valve
weight
diaphram
gas supply passage
to burner
VALVE CLOSED
MAIN GAS SUPPLY

FIGURE C

Figure D shows one type of Bimetal operated diaphram valve. The only difference in this valve and the other diaphram valve is the method in which the bleed orifice is opened. An electric heater is placed on dissimilar metals which warp when heated. When the 24 volt heater is energized the bimetal warps, opening the bleed orfice, allowing pressure above the diaphram to bleed off. Because the pressure below the diaphram is greater the weight and disc are lifted by the gas pressure and gas flows to the main burners.

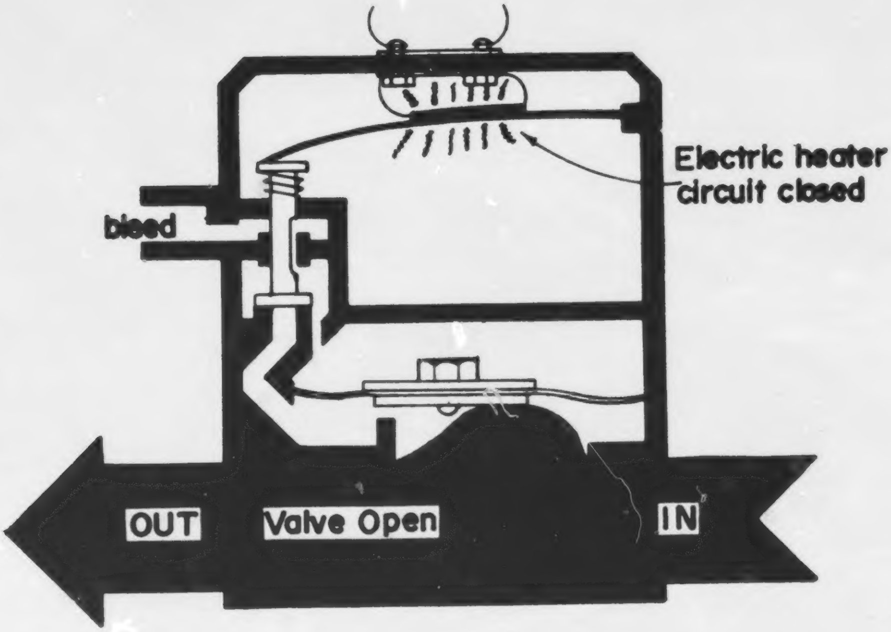


FIGURE D

Figure E shows another type of bimetal operated valve that lifts the disc off the seat directly rather than controlling a bleed orifice. All bimetal valves have delayed openings due to the time necessary to produce enough heat to warp the bimetal and delayed closing due to the time necessary for the valve to cool.

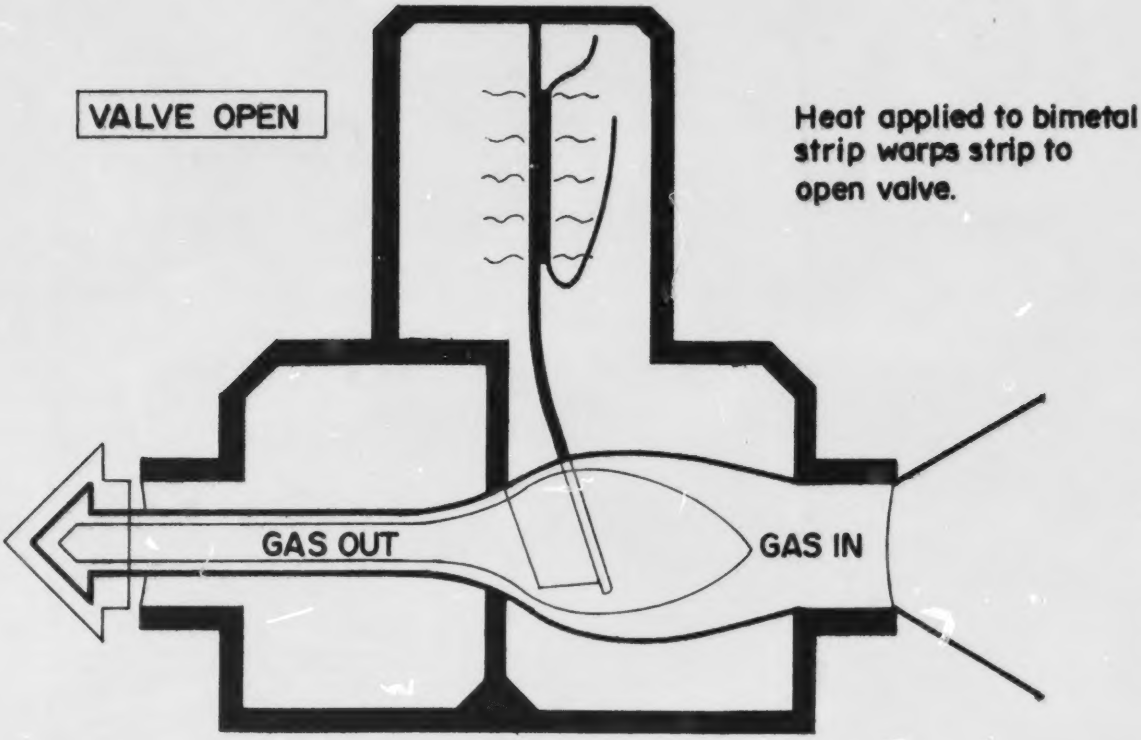

VALVE OPEN
Heat applied to bimetal strip warps strip to open valve.
GAS OUT
GAS IN

FIGURE E

Figure F illustrates the heat motor which uses the heat given off by an electrical heating coil (24 volt) to move an expansible rod. The slight movement of this rod opens and closes the valve. When the rod is not energized (Figure F) the valve is kept closed by a spring. Figure G shows the valve after the heating element has been energized causing the rod to expand and snap the valve to the open position. This valve will also be delayed in opening and closing due to time necessary for the heater to warm and for the rod to cool after the heater is de-energized.

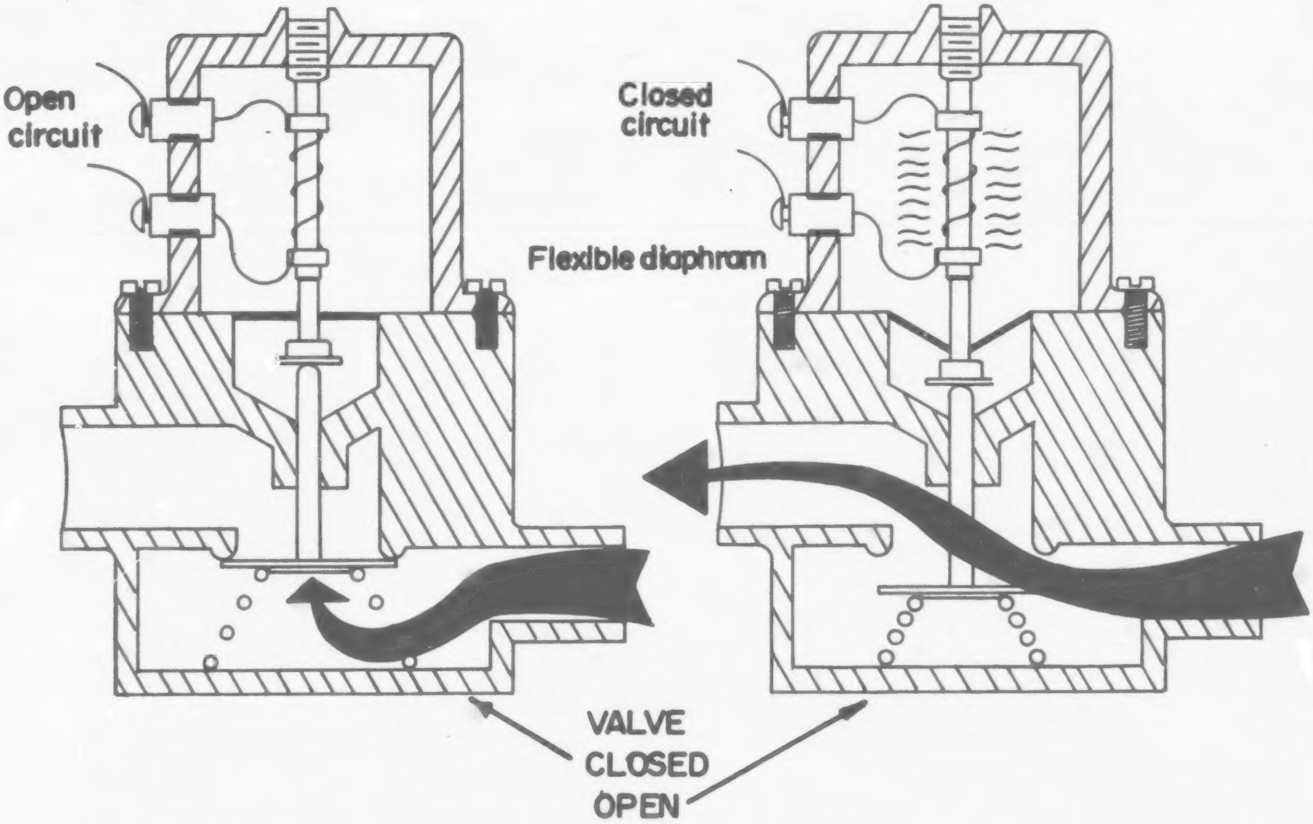

Open circuit
Closed circuit
Flexible diaphram
VALVE
CLOSED
OPEN

FIGURE F

FIGURE G

1. The operating noises in a solenoid type gas valve have been lessened by the addition of:

   a. a rubber or plastic seat
   b. a spring to slow opening clack
   c. oil filled
   d. vapor chamber

2. The primary force used to open or close a diaphram type gas valve is:

   a. the weight
   b. a spring
   c. main gas opening
   d. a bleed off valve

3. The coil of a magnetic diaphram valve merely controls:

   a. a weight
   b. a diaphram
   c. main gas opening
   d. a bleed off valve

4. With the coil energized and the gas supply passage closed, pressure above the diaphram bleeds off and the valve will:

   a. close
   b. open
   c. overheat
   d. chatter

5. The bimetal diaphram valve differs from the magnetic diaphram valve:

   a. in physical size
   b. size of diaphram
   c. length of bleed tube
   d. in the method of opening and closing of bleed orfice

6. The bimetal warps from heat applied by:

   a. a pilot flame
   b. a 24 volt heater
   c. ignition transformer
   d. main gas burner

7. The heat motor uses the heat given off by a 24 volt heating coil to:

   a. open a bleed orfice
   b. lift a weight
   c. light a diaphram
   d. move an expansible rod

8. Which valves listed below are direct acting valves controlling the main gas opening?

   a. solenoid type
   b. diaphram
   c. bimetal
   d. heat motor

9. Which valves listed below control a bleed off orifice with the main valve opened and closed by pressure difference?

   a. solenoid type
   b. magnetic diaphram
   c. bimetal diaphram
   d. heat motor

10. If the bleed port on a diaphram type valve becomes clogged:

    a. the valve will remain open
    b. the valve will remain closed
    c. the valve will overheat
    d. the valve will leak

Procedures:

1. Secure the gas valves for disassembly.

Solenoid type
- A. Completely disassemble a solenoid type valve.
- B. Discuss with the instructor.
- C. Reassemble the valve.

Diaphram type
- A. Completely disassemble a diaphram type valve.
- B. Discuss with the instructor.
- C. Reassemble the valve.

Bimetal type
- A. Completely disassemble a Bimetal type valve (diaphram or direct acting).
- B. Discuss with the instructor.
- C. Reassemble the valve.

Heat Motor type
- A. Completely disassemble a Heat Motor type valve.
- B. Discuss with the instructor.
- C. Reassemble the valve.

Procedures:

1. Remove a gas valve from an operating gas furnace. Your instructor will make assignment.
    A. Cut off power.
    B. Cut off gas supply.
    C. Remove gas pipe from union to gas valve.
    D. Remove the wires from the gas valve.
    E. Remove the pilot line and thermocouple from gas valve.
    F. Remove the gas valve.

2. Ask for an Instructor check.

3. Re-install the gas valve.
    A. Apply pipe dope to all fittings.
    B. Reverse the removal procedure to re-install the valve.

4. Ask for an Instructor check.

5. Operate the furnace.

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Installing & Servicing Pilot Ignition Devices **TIME (est.)** **(act.)**

UNIT NO HE-10

OBJECTIVE(S)

Diagnose problems in pilot ignition devices.

START ➔ A-1 W-1 C-1 W-2 C-2 L-1 C-3
W-3 L-2 C-4 A-2 C-5 L-3 C-6 W-4 C-7
L-4 C-8

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-10a
W-2 Text Assignment HE-10a
W-3 Information Sheet HE-10b
W-4 Information Sheet HE-10c
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-10a
L-2 Job Sheet HE-10b
L-3 Job Sheet HE-10c
L-4 Job Sheet HE-10d
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-10a
A-2 Slide Set HE-10a
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 Instructor Check
C-6 Instructor Check
C-7 Instructor Check
C-8 Instructor Check
C-9

The most commonly used pilot burner is patterned after the Bunsen burner frequently used in laboratories. This type burner entrains primary air as the gas in introduced into the pilot. The air is then mixed in the venturi section with the gas. The air-gas mixture is then burned at the burner ports. At this point secondary air is drawn into the flame for completion combustion.

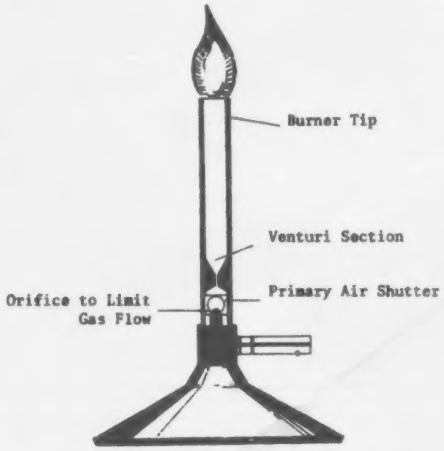

Burner Tip
Venturi Section
Primary Air Shutter
Orifice to Limit Gas Flow

FIGURE A

Figure (B) is a cut away of an actual pilot burner. One of the chief problems with pilot burners is the primary air inlet becoming closed. This is caused by the dust and lint in the air. Figure C shows how this problem was corrected in one type of pilot burner. The original design (Figure C, number 1) had too high primary air velocity. This was temporarily solved by the addition of more primary air ports and the addition of an air screen, (Figure C, number 2) however, in a short time the screen became clogged with dust. In Figure C, number three, the final design eliminated the sharp right angle and increased the diameter of the primary air port. This allowed the dust particles to be carried through to the burner tip where they could be incinerated.

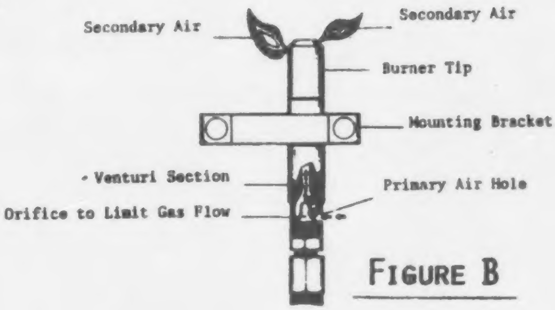
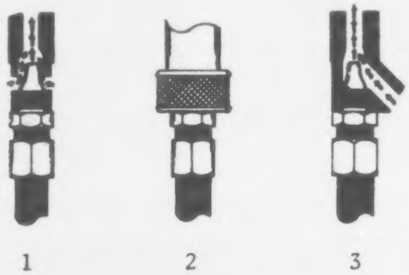

Secondary Air
Secondary Air
Burner Tip
Mounting Bracket
Venturi Section
Primary Air Hole
Orifice to Limit Gas Flow

FIGURE B

FIGURE C



Primary air is also affected by the angle of the pilot orifice holes. As Figure D shows, the different angles are necessary for the different gases to be used. Manufactured gas requires very little primary air so the holes are not at a sharp angle. LP gas requires a lot of primary air therefore the holes are almost parallel. Natural gas falls somewhere in between.

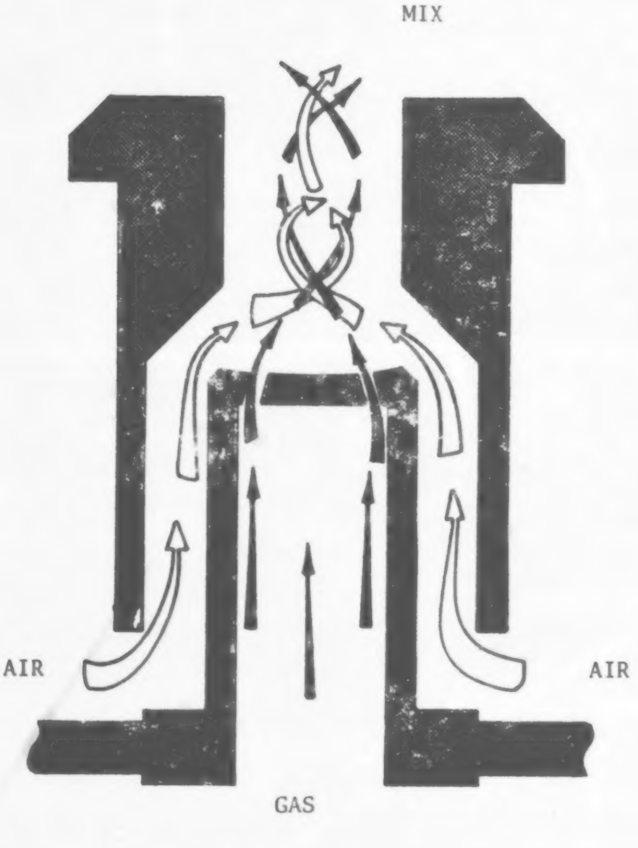


FIGURE D

In order to fit a specific burner ignition problem pilot burners come in many shapes and designs. They may be mounted vertically or horizontally or at some angle in between. The pilot flame must envelop the thermocouple tip from 3/8" to 1/2" to insure proper heating. The pilot flame must also light the main burner. For these reasons a deflection tip is usually added to the burner to direct the flame to the thermocouple and the main burner. Figure E shows some commonly used tips.

TYPES OF TIPS

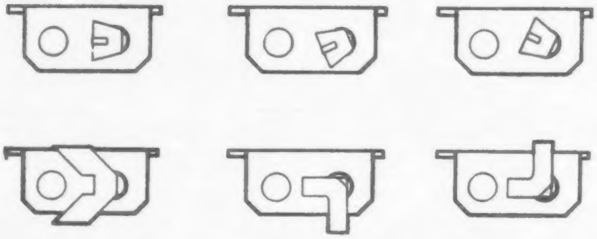


FIGURE E

The pilot burners used on direct spark ignition, glow coil, and spark ignition of a pilot flame are very similar in design to the pilot burner used on thermocouple systems. They vary only in mounting position and tip design.

A direct spark ignition system ignites the main burners with a high voltage spark. There is no pilot flame used. The components of a direct spark system include the primary system control, a flame sensor, a spark igniter, and the main gas valve.

The system control, an electronic device, performs several functions. It may include a 24 volt transformer which provides power for the main gas valve. It also generates up to 25,000 volts for spark ignition of the main burner. It will discontinue ignition spark when the flame is established, or go into safety lock out if the main burner fails to ignite. It protects against both flame out and momentary interruption of electrical power.

The flame sensor is a flame rod supported in a ceramic insulator with a mounting bracket. The sensor is immersed in the main burner flame, with the main burner head acting as ground. It operates on the flame rectification principal. In the presence of the main burner flame a DC current is established to prove ignition and continuously monitor the flame during the burner on period.

The spark ignition powered by the primary system control produces a spark for direct ignition of the main burner. It consists of an inner electrode (insulated rod) and an outer electrode which is a rigid formed strap bent at the end to extend over the tip of the inner rod. The tip of the electrode extends into the path of the main burner gas; arcing across the spark gap ignites the burner.

The main gas valve is controlled by the thermostat. Its operation also depends on the primary system control and a conventional high limit switch. If the main burner fails to ignite within 4 to 10 seconds the primary control will lockout. In order to restore operation the thermostat must be cut off then back on. Figure F is a wiring diagram of a typical direct spark system. The manufacturers procedures must be followed to troubleshoot these systems.

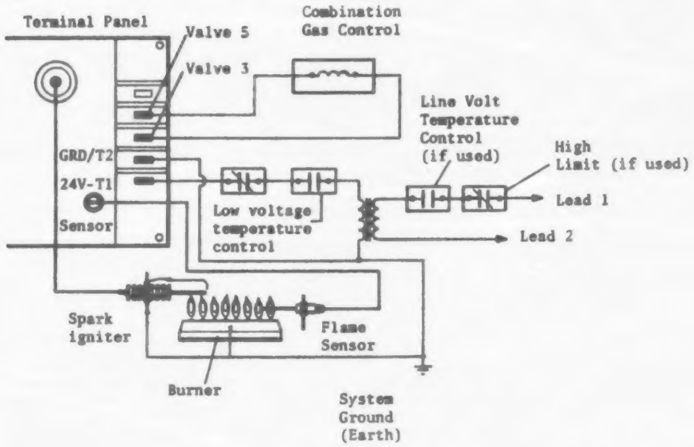
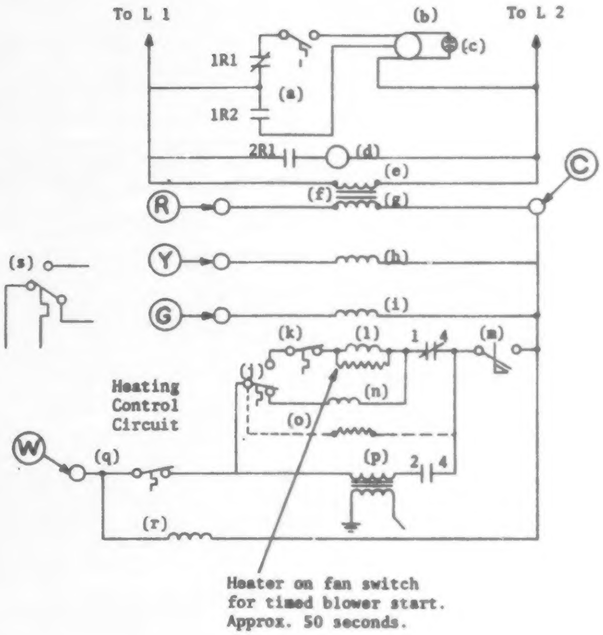

Terminal Panel
Valve 5
Combination Gas Control
Valve 3
Line Volt Temperature Control (if used)
High Limit (if used)
GRD/T2
24V-T1
Lead 1
Sensor
Low voltage temperature control
Lead 2
Spark igniter
Flame Sensor
Burner
System Ground (Earth)

FIGURE F

Figure G is a diagram of a system that uses a high voltage spark to ignite the pilot flame. When the pilot flame is established a mercury or expansible rod flame sensor cuts off the ignition transformer and establishes a circuit to the main gas valve. A time delay relay or sequencer provides for a timed ignition cycle, if the pilot fails to ignite in this period the sequencer interrupts the power and after a short time it will try to ignite the pilot again. This system uses no electronic controls and is easy to troubleshoot using conventional methods.


To L 1
(b)
To L 2
(c)
1R1
(a)
1R2
2R1
(d)
(e)
C
R
(f)
(g)
(s)
Y
(h)
G
(i)
(k)
(l)
1
4
(m)
(j)
(n)
Heating
Control
Circuit
(o)
W
(q)
(p)
2
4
(r)
Heater on fan switch
for timed blower start.
Approx. 50 seconds.

a. Blower SW
b. Blower motor
c. Blower motor run cap
d. Combustion air blower (Relay 2R)
e. 208-230v. Primary
f. Control trans
g. 24v. Secondary
h. Contactor coil
i. Blower relay 1R
j. Mercury flame sensor
k. Limit
l. Gas valve
m. Combustion air sail SW
n. Sequencer
o. Pilot valve (prop only)
p. Ign. trans
q. Rev. air SW
r. Combustion air blower Motor relay 2R
s. Rod flame sensor

FIGURE G

Procedure

1. To complete this package you will need the following:

    a. thermocouple
    b. millivoltage solenoid
    c. prestolite torch
    d. baso millivolt tester

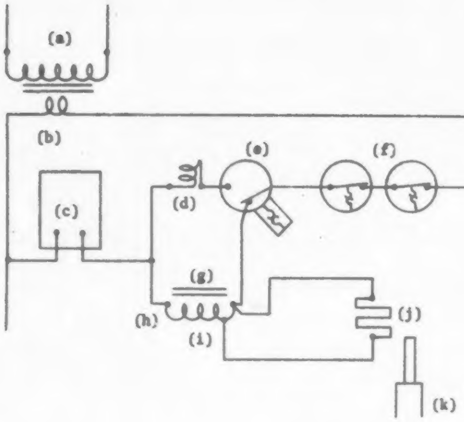
2. Mount the thermocouple in a vice, connect the millivolt tester to the thermocouple leads (cold junction). Use the prestolite torch to heat the thermocouple tops (1/2 inch) to a dull red. Observe the millivolt reading (minimum 18 millivolts), remove the heat and observe the voltage drop. This is called an open circuit test.

3. Screw the thermocouple into the millivoltage solenoid. Heat the thermocouple and hold the solenoid closed (about 1 minute) the solenoid should remain closed when released. Observe the millivoltage reading - (minimum 7 millivolts). Remove the heat and observe the millivoltage reading when the solenoid drops out. This is called a closed circuit test.

4. Discuss the test or any questions you migh have with the instructor. Allow the thermocouple to cool and return all equipment to the proper place.

A bimetal switch consists of two dissimilar metals fused together to form one. These metals when heated, expand at different rates causing a warping action or movement. Bimetal switches are made which close or open at the same time that another circuit is completed. The bimetal safety switch receives heat from the pilot flame.

A study of the circuit in Figure H will show how the bimetal switch, identified as a flame detector in this circuit establishes a circuit to the glow coil. At this time the pilot flame is not burning, however gas is escaping through the pilot orifice. With the power on, the glow coil becomes red hot, igniting the pilot flame which causes the flame detector (bimetal) to warp changing the contact from the position shown. This action cuts the glow coil off and allows voltage to go to the main gas valve which opens, and the main burner is ignited.



a. 120V a-c
b. 24V a-c
c. Room thermostat
d. G.V.
e. Flame detector
f. High limit switches
g. 24V a-c
h. Glow coil transformer
i. 2.5V a-c
j. Glow coil
k. Pilot light

FIGURE H

Failure of the pilot flame de-energizes the gas pilot valve and energizes the glow coil. If it fails to light, the main gas valve cannot be energized, thus providing safety operation of the unit. In this system the pilot gas is allowed to escape to the atmosphere. This system is not used on LP gas. Figure I shows some common bi-metal actuators, the two in the center are used as pilot safety devices.

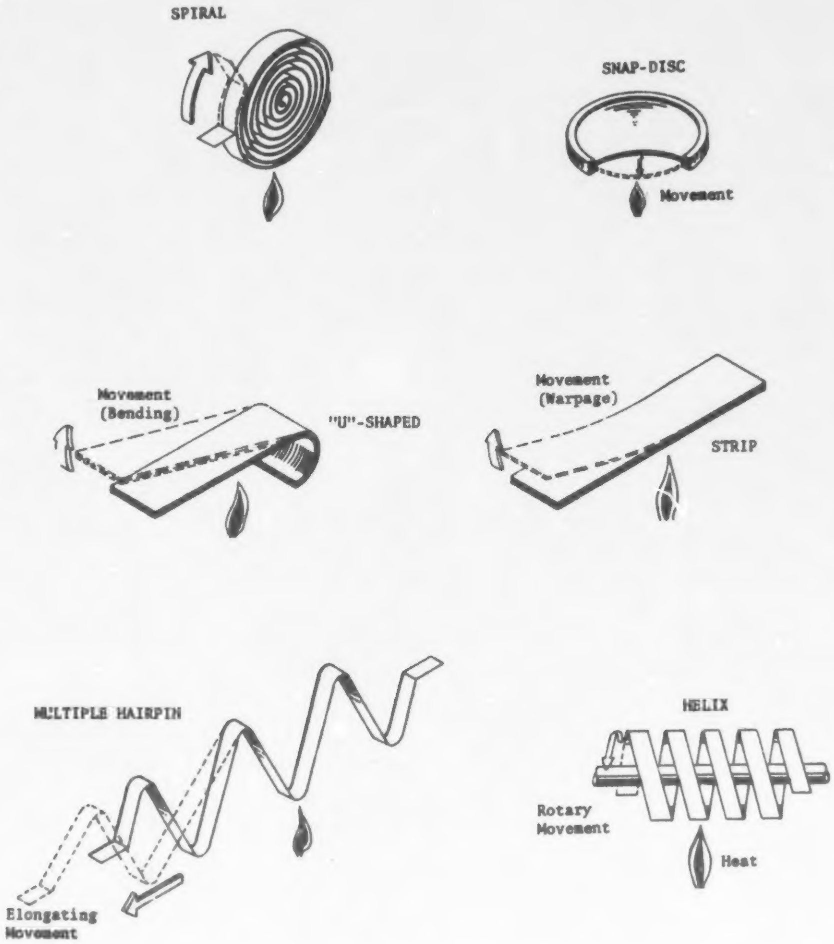
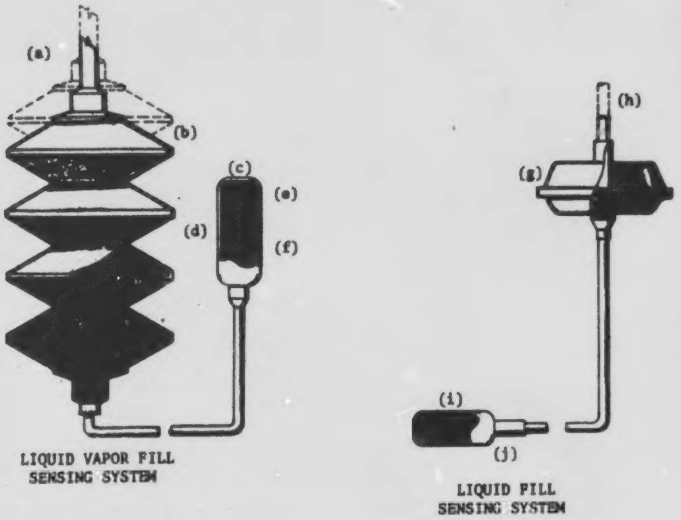

SPIRAL
SNAP-DISC
Movement
Movement
(Bending)
"U"-SHAPED
Movement
(Warpage)
STRIP
MULTIPLE HAIRPIN
HELIX
Rotary
Movement
Heat
Elongating
Movement

FIGURE I

In Figure J the uniform expansion of the liquid (mercury) is used to expand a diaphram which in turn will open or close a switch. The switching arrangement may break one circuit when it makes another one. As with the bimetal switch, heat from the pilot flame will keep the circuit to the gas valve closed. Should the pilot flame be extinguished the main gas valve is cut off. There is a short delay due to the time required for the bulb to cool.



LIQUID VAPOR FILL SENSING SYSTEM

LIQUID FILL SENSING SYSTEM

a. To temp controller mechanism
b. Bellows
c. Heat
d. Remote temp sensing bulb
e. Pressure
f. Liquid
g. Diaphragm
h. To temp controller mechanism
i. Heat
j. Remote temp sensing bulb

FIGURE J

Procedure: Your instructor will assign you three gas furnaces, you will determine the ignition type and pilot safety type device used on each unit.

UNIT ONE Model No. _____ Serial No. _____

Check one:

☐ Manually lit standing pilot w/thermocouple 100% safety
☐ Manually lit standing pilot w/mercury safety
☐ Glow coil ignition, standing pilot w/bimetal safety
☐ Automatic spark ignition of pilot w/rod or mercury flame sensor
☐ Other: describe

UNIT TWO Model No. _____ Serial No. _____

Check one:

☐ Manually lit standing pilot w/thermocouple 100% safety
☐ Manually lit standing pilot w/mercury safety
☐ Glow coil ignition, standing pilot w/bimetal safety
☐ Automatic spark ignition of pilot w/rod or mercury flame sensor
☐ Other: describe

UNIT THREE Model No. _____ Serial No. _____

Check one:

☐ Manually lit standing pilot w/thermocouple 100% safety
☐ Manually lit standing pilot w/mercury safety
☐ Glow coil ignition, standing pilot w/bimetal safety
☐ Automatic spark ignition of pilot w/rod or mercury flame sensor
☐ Other: describe

Procedure:

1. Your instructor will assign you to a working gas furnace.
2. Follow the lighting instructions on the furnace, light the pilot.
3. Turn the power on and allow the main burner to light. Observe normal operation, make sure that the draft created by the main burner flame does not pull the pilot flame away from the thermocouple.
4. Create problems and observe operation.
    1. Loosen thermocouple.
    2. Turn pilot adjusting screw in so that the flame is not in good contact with the thermocouple.
    3. Discuss any problems with the instructor.

There are electronic ignition systems on some deluxe furnaces that use the direct spark principle to light a pilot flame. That is they have an electronic module to create the spark and provide ignition. In this respect they perform the same as true direct spark ignition systems, however, on these systems a conventional pilot flame will light the main burner. Figure (K) is such a system. Figure (L) shows the mounting arrangement of the electrode, sensing probe and pilot flame.

You must follow the manufacturers troubleshooting guide to determine if the module is performing correctly.

There are other systems on the market that use a spark to light the pilot flame that are not electronic. They are fairly easy to troubleshoot using conventional methods. (See Figure M, on the following page, which is an example of a wiring diagram.)

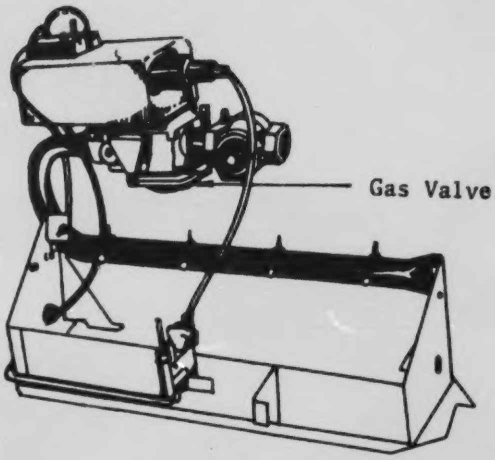
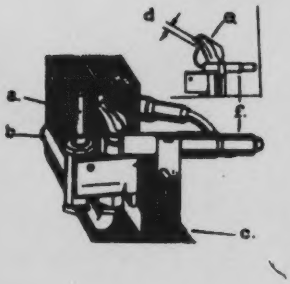


FIGURE K

The "brain" of this system is a 24 volt sequencer (time delay relay). This sequencer controls a normally closed and a normally open switch. Because this is an outdoor unit there is a combustion air blower that must run when the main burner is on, a combustion air sail switch proves that the combustion air blower is providing combustion air. A mercury (liquid filled) flame sensor or rod type sensor is used to prove that the pilot flame has been established. An ignition transformer provides the necessary spark to ignite the pilot.

Starting from a cold position (no pilot flame) this is the sequence. (1) The thermostat R & W close energizing the combustion air blower relay 2r. The combustion air blower then starts, closing the combustion air switch. The sequencer is energized through the NC contacts 4-1 and in approximately 30 seconds contacts 4-1 open and contacts 4-2 close. This action removes the sequencer from the circuit and energizes the ignition transformer. The pilot should light immediately and begin to heat the flame sensor.



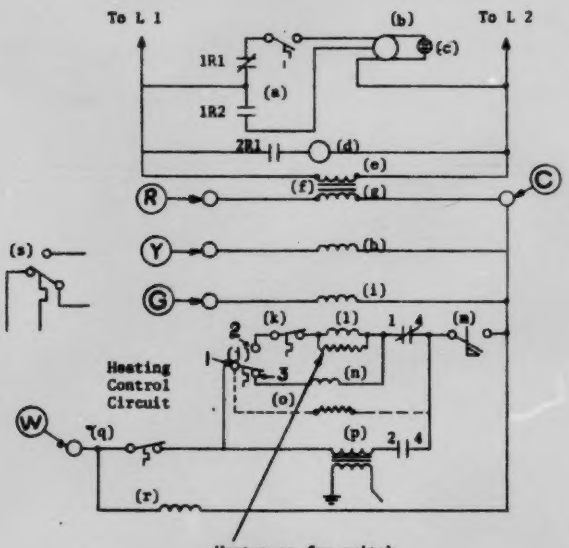
a. Sensing probe
b. Pilot gas tubing
c. Manifold bracket
d. .100 gap
e. Pilot shield
f. Ceramic electrode

FIGURE L

The flame sensor when hot will break the circuit 1-3 to the seqencer and make a circuit 1-2 to the main gas valve. During this time the sequencer has been cooling down and when it cools the contacts 4-2 open removing the ignition transformer from the circuit and closing the contacts 4-1 which will provide a complete circuit to the gas valve. The main burner is now lit and in approximately 50 seconds the indoor fan will start.

When the thermostat is satisfied the combustion air motor relay cuts the combustion blower off, the combustion air sail switch opens and the main gas valve is de-energized. On natural gas models the pilot will continue to burn and when the thermostat again calls for heat, it energizes the combustion air relay which starts the combustion air blower, this in turn closes the combustion air sail switch completing the circuit to the main gas valve. In other words pilot flame is established only the sail switch prevents the main gas valve from being energized.

LP models have a pilot gas valve that cuts the pilot flame each cycle to provide for 100% safety. Thus, LP models go through a cold start each time the thermostat calls for heat.



Heater on fan switch for timed blower start. Approx. 50 seconds.

a. Blower SW
b. Blower motor
c. Blower motor run cap
d. Combustion air blower (Relay 2R)
e. 208-230v. Primary
f. Control trans
g. 24v. Secondary
h. Contactor coil
i. Blower relay 1R
j. Mercury flame sensor
k. Limit
l. Gas valve
m. Combustion air sail SW
n. Sequencer
o. Pilot valve (prop only)
p. Ign. trans
q. Rev. air SW
r. Combustion air blower Motor relay 2R
s. Rod flame sensor

FIGURE M

Procedure:

1. The instructor will assign you a unit with Intermittent Pilot and spark ignition (example Tappan RTA series).
2. You will observe normal operating sequence (cold start).
3. Discuss operation with your instructor.
4. Troubleshoot this system. (Instructor will make problems in the unit).

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Installing and Servicing Combination Gas Valves **TIME (est.)** **(act.)**

UNIT NO HE-11

OBJECTIVE(S)

Troubleshoot and replace combination gas valves.

START → W-1 → W-2 → A-1 → W-3 → C-1 → L-1 → C-2 → A-2 → L-2 → C-3

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-11a
W-2 Text Assignment HE-11a
W-3 Assignment Sheet HE-11a
W-4
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-11a
L-2 Job Sheet HE-11b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-11a
A-2 Slide Set HE-11b
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4
C-5
C-6
C-7
C-8
C-9

At this point you have studied about all the components of a combination gas valve. Each component was studied separately in order to have a clear concept of the operation and function of each type.

The combination valve is a fairly recent development. Its name is derived from the fact that all of the components traditionally installed on the gas manifold to make it automatic and safe are included within the one valve.

There is a manual control for ignition and normal operation. Its control positions are OFF, PILOT and ON. In the "OFF" position gas cannot flow through the valve. In the pilot position gas will flow to the pilot orifice only. An additional safety factor is that the off control on a separate knob or button must be depressed at the same time the control knob is set at "PILOT" in order for gas to flow to the pilot. In the "PILOT" position the pilot flame is lit. Once the pilot flame is established the knob is turned to the "ON" position. In the "ON" position gas will flow to the main burner when the main gas solenoid is energized by the thermostat. The National Gas Code requires that a manual cut off be installed in the gas supply. The manual controls of the combination valve will not satisfy those requirements.

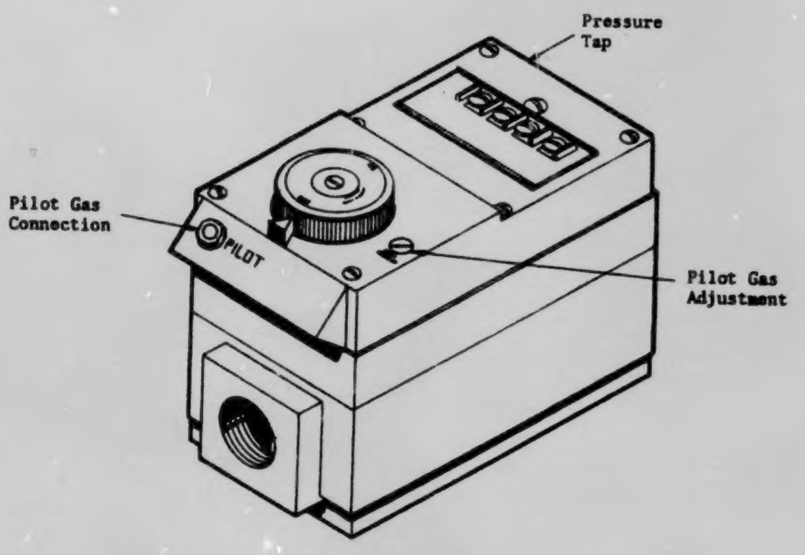


FIGURE A

The second component of the combination valve features the pilot supply, adjustment, and safety cut off. The pilot supply consists of internal porting or routing of the gas to the pilot orifice. A millivoltage solenoid provides 100% safety by controlling flow of all gas through the valve. The second component also provides a connection for the thermocouple which supplies the millivolts needed to operate the solenoid. The pilot flame size can be varied by an adjustment screw located on the combination valve.

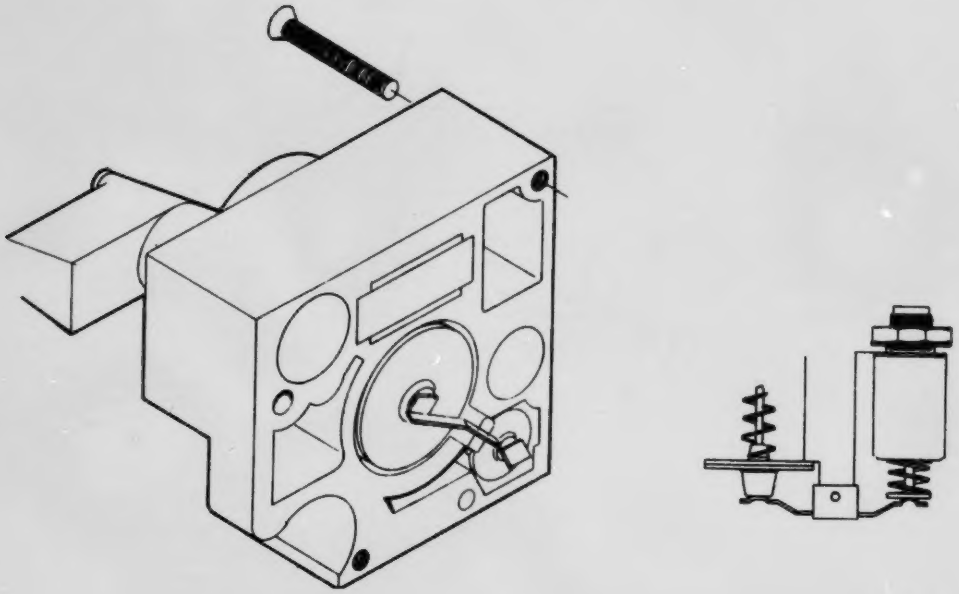


FIGURE B

The next component is a pressure regulator (natural gas models only.) On the pressure regulator an adjustment screw will allow you to adjust the pressure to the required 3 1/2 inches of water column. The adjustment screw is accessable only after you have removed a cover screw. A manometer must be connected to the burner manifold or at a pressure tap provided on the outlet side of the valve.

The final component is the on-off solenoid controlled by the thermostat. This is usually 24 volts and as you know from previous study it is not always a solenoid coil. It could be a 24 volt heater used to heat a bimetal or heat motor.

Valves from various manufacturers may differ, but they all accomplish these same functions.

1. What four components previously installed separately on the gas manifold are built in to the combination gas valve?

2. With the manual control of the combination valve in the pilot position and the knob depressed can the main burner be lit?

3. Explain how the pilot is lit before the thermocouple is hot.

4. With the manual control of the combination valve in the on position, when will gas flow to the burners?

5. Explain how the thermocouple provides 100% safety.

6. Can the pilot flame size be adjusted? How?

7. Do combination valves used on L.P. systems contain a pressure regulator?

8. How is the manifold pressure on a natural gas system adjusted?

9. What automatic device controls the entrance of all gas into the main gas valve?

10. If the thermostat is calling for heat and 24 volts is applied to the main gas valve can gas flow to the burners if the manual control knob is set in the pilot position?

Procedure:
1. Obtain a combination gas valve from the supply room
2. Tear the valve down, if you have questions see your instructor
3. Fill out the data sheet below on the valve

1. Test the millivoltage solenoid coil, is it good?

☐YES ☐NO ☐OPEN ☐SHORTED

2. Test the main operator coil, is it good?

☐YES ☐NO ☐OPEN ☐SHORTED

3. What type is the main operator coil?

☐SOLENOID ☐BI-METAL ☐HEAT MOTOR

4. Inspect the regulator diaphram. Is it in good condition?

☐YES ☐NO

5. What should the amp draw of the valve be?

________ amps

Procedure:

1. Obtain a Universal replacement combination valve from the supply room.
2. You will also need 2 pipe wrenches, pipe dope, a 6 inch adjustable wrench, needle nose pliers, soap bubbles, a manometer, an amp meter and a small screwdriver.
3. Install the valve on a working gas furnace:
    a. Cut off the gas supply to the furnace, cut off 155 volt main breaker.
    b. Always using two pipe wrenches, remove all the pipe between the cut off and the existing gas valve.
    c. Remove the wires from the valve using needle nose pliers.
    d. Remove the pilot gas line and thermocouple.
    e. Using two wrenches, remove the existing gas valve.
    f. Using the pipe plugs provided in the kit, plug all the holes not needed in this installation. Use pipe dope on all fittings.
    g. Reverse the removal procedure, install new valve, connect pilot tube, thermocouple and wires. Connect the pipe between the valve and the cut off, use pipe dope on all fittings.
    h. Turn the main gas supply back on.
    i. Use soap bubbles and leak test all connections.
    j. If there are no leaks, follow the instructions on the furnace for lighting the pilot. Allow time for air to escape before attempting to light the pilot.
    k. Check the pilot flame. It should be a soft blue flame and should envelop the thermocouple "hot junction" from 3/8 to 1/2 inch. Clean pilot assembly or adjust pilot flame if needed.
    l. Extinguish the pilot flame, use your watch to time the drop out time. The maximum drop out time is 2 1/2 minutes. Listen for a click when the valve closes.
    m. With the 115 volt main breaker still off, remove the test plug from the burner manifold and replace it with a half union or a B-valve. Connect the manometer hose to the half union.
    n. Restore power to the furnace. Set the room thermostat up and allow the main burner to operate.
    o. The manifold pressure should be 3 1/2 inches of water column. If the pressure is above or below 3 1/2" adjust the regulator.
    p. Use the amp meter to determine gas valve amp-draw, set the heat anticipator to match this amp draw.
    q. Ask your instructor to check your installation.

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Servicing Burners **TIME (est.)** **(act.)**

UNIT NO HE-12

OBJECTIVE(S)

Remove and service burners on gas furnaces.

START ➔ W-1 W-2 C-1 A-1 C-2 L-1 C-3
L-2 C-4

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-12a
W-2 Assignment Sheet HE-12a
W-3
W-4
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-12a
L-2 Job Sheet HE-12b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-12a
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5
C-6
C-7
C-8
C-9

The purpose of the gas burner is to properly mix the primary air and the gas. It also delivers this mixture to the combustion area to be burned.

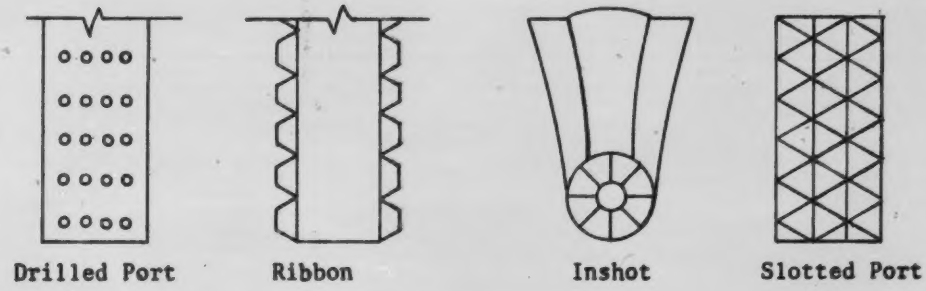
When the thermostat calls for heat, the main gas valve is opened and gas flows from the valve into the manifold. Along the manifold at each burner outlet there is a spud which has a precisely drilled orifice to meter the correct amount of gas. The spud is located in the center of the burner face. The burner face also contains the primary air opening. This opening is usually fitted with adjustable shutters which allows adjustment of the primary air.

When the gas is injected into the burner venturi, a negative pressure is created behind it. Primary air is thus drawn into the burner venturi where it mixes with the gas. As the mixture comes out of the burner ports it is ignited by a pilot flame or spark thus the heating flame is established. The amount of secondary air is dependent upon the heat exchanger design and is not adjustable.

It is generally recognized that a good gas flame should be a sharp blue color. Closing the primary air shutters reduces primary air and causes the flame to turn yellow therefore resulting in incomplete combustion. Fully open shutters will allow too much primary air causing the flame to lift off the burner ports. The flame will then be noisy and could blow itself out. Carbon monoxide may also be released.

There are two types of gas burners. The power burner, and the atmospheric injection burner.

The most common burner used on residential gas furnaces is an atmospheric type. The four most common designs of burners used are the drilled port, the slotted port, the ribbon and the inshot (See Figure A). The drill port burner is usually made of cast iron and the ports are drilled. The slotted part is probably made of stamped steel similar to the ribbon and inshot burner. The ribbon burner, however, may also be made of cast iron. It gets its name from the fact that there is a continuous ribbon of flame down each side of the burner.



Drilled Port

Ribbon

Inshot

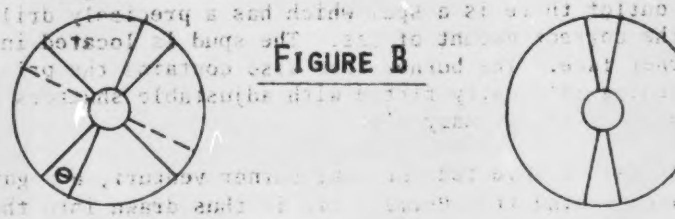
Slotted Port

TYPES OF BURNERS

FIGURE A

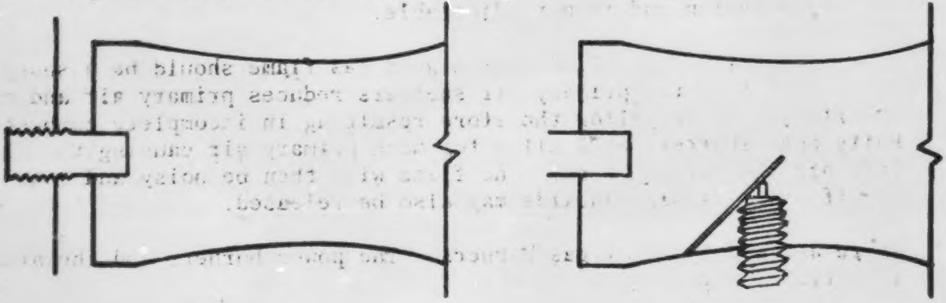
The inshot burner is so simple it actually has no burner head. In this burner a screw regulates the primary air by disturbing the high velocity gas stream. Figure B shows four types of primary air adjustment for gas burners.

FIGURE B



A. Adjustable Shutter

B. Nonadjustable Shutter



C. Threaded Shutter

D. Deflector Shutter

Power burners are not usually found on residential furnaces. The power burner uses a blower to force both primary air and secondary air into the burner. The burner tube has angular vanes to spin or twirl the flame for more efficient burning. It operates similar to a gun type oil burner and is frequently used on boilers and other commercial equipment. An automatic electric pilot ignition is used that incorporates a 6,000 volt transformer to provide the necessary spark to ignite the pilot gas, Figure C shows a typical power burner.

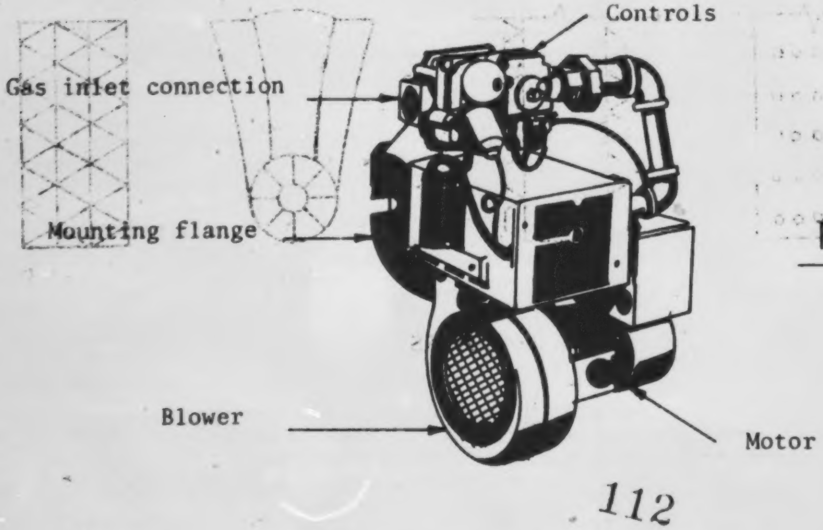


FIGURE C

The single orifice inshot burner is used on water heaters and some residential furnaces. It usually directs the flame against a deflector or target plate in order to spread the flame.

Residential gas furnaces may be one of three designs:

1. Airflow up through the heat exchanger (upflow)

2. Airflow down through the heat exchanger (downflow)

3. Airflow across the heat exchanger (horizontal)

A very popular system now in use in residential applications is the rooftop or combination gas unit which is a packaged air conditioner (electric) combined with a horizontal gas furnace approved for outdoor use. These systems usually use forced draft, in other words a small blower provides combustion air (See Figure D). The actual burners are usually pressed steel and have no primary air adjustment. Some of these systems pressurize the burner compartment as in Figure D. Others have the blower on the outlet of the heat exchanger and pull the combustion air across the burner.

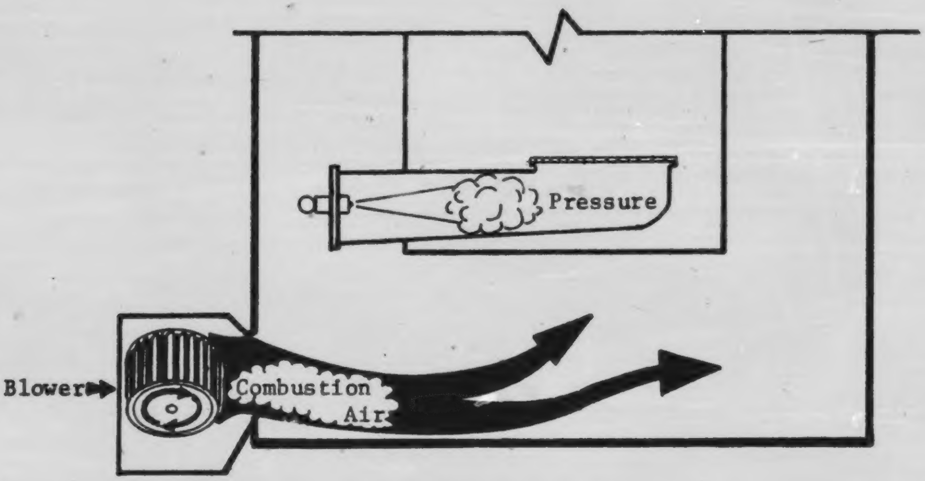


FIGURE D

1. What is the purpose of the gas burner?
2. The part which screws into the gas manifold and contains the gas orifice is called ______________.
3. Explain how primary air is admitted to the burner.
4. What is the effect of reduced primary air (closed shutters)?
5. What is the effect of too much primary air (fully open shutters)?
6. Name four types of atmospheric burners.
7. Name four types of primary air shutters.
8. On what type equipment are power burners usually found?
9. What are the three designs of gas furnaces.
10. What type equipment uses forced draft?

PROCEDURE: You will correctly adjust the primary air on two gas furnaces. See your instructor for assignment. Look for these types of flames.

Yellow Flame: This flame has a small blue colored area at the bottom. The outer part of the flame is yellow and smoking. The flame is yellow because of insufficient primary air. Incomplete combustion in this case will result in a dangerous condition that cannot be allowed. (See Figure A).

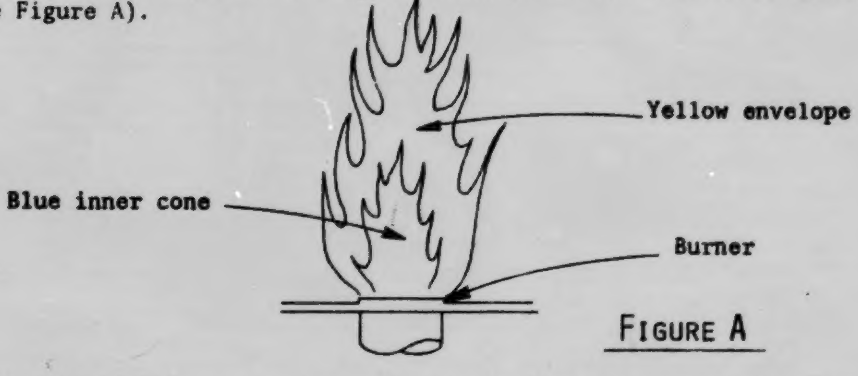

Yellow envelope
Blue inner cone
Burner

FIGURE A

Yellow Tipped Flame: Another undesirable flame is caused by having insufficient primary air. It will produce carbon which will block the furnace flues. (See Figure B).

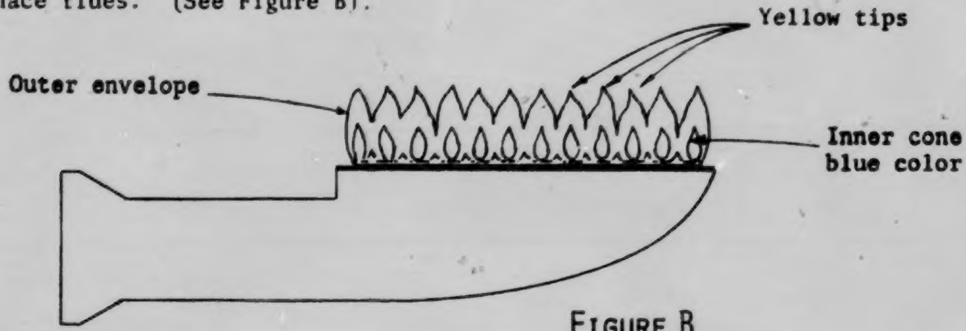

Yellow tips
Outer envelope
Inner cone blue color

FIGURE B

Orange Colored Flame: This flame is usually a temporary condition caused by dust in the air. Bump the burners during operation and you will see this flame. (See Figure C).

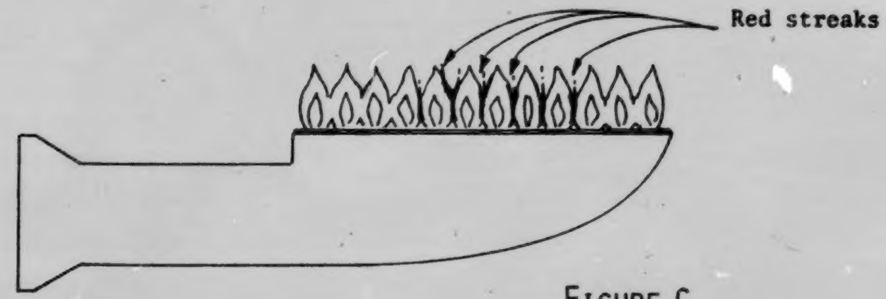

Red streaks

FIGURE C

Soft Lazy Blue Flame: This flame is a result of just enough primary air, the yellow tips have just disappeared. The inner cone and outer envelope are not as clearly defined as in a proper blue flame. (See Figure D).

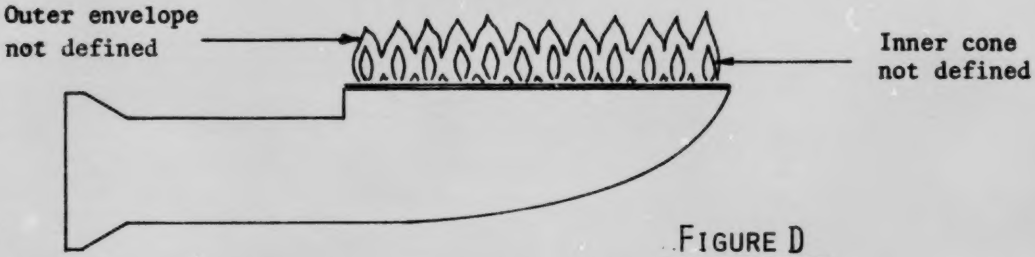

Outer envelope not defined
Inner cone not defined

FIGURE D

Sharp Blue Flame: This is the proper flame when the air and gas mixture are just right. The inner cone and outer envelope are clearly defined and will be pointed and straight. The flame will rest on the burner ports and there will not be a blowing noise. This is the most desirable gas flame. (See Figure E).

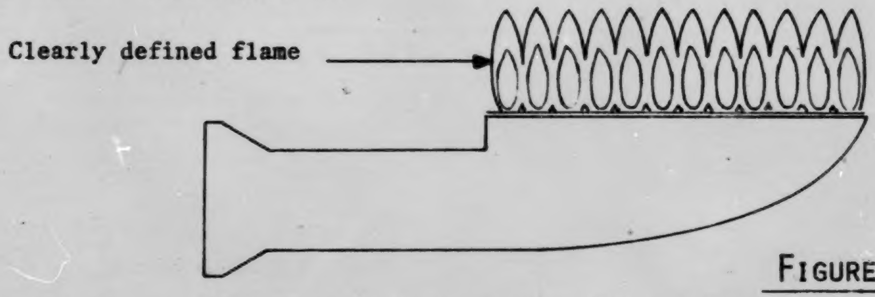

Clearly defined flame

FIGURE E

Lifting Flame: This flame is produced when there is too much primary air. This is an undesirable flame. When the flame lifts, the intermediate products of combustion will escape to the atmosphere. The flame will be small and noisy like a torch that is turned too high. Ignition will also be rough. (See Figure F).

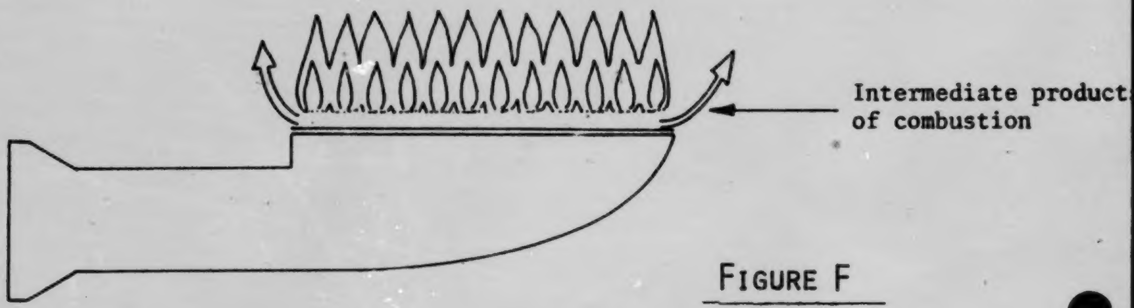

Intermediate product
of combustion

FIGURE F

Floating Flame: This flame is due to a lack of secondary air. It appears as a floating cloud drifting around over the burners wherever it can find secondary air for combustion. The abnoxious odor of aldehydes will be present even if the flame clears somewhat when the furnace door is opened. This flame is also produced when the heat exchanger is plugged with soot or rust or when the vent is plugged. This is a dangerous flame that must be corrected. (See Figure G).

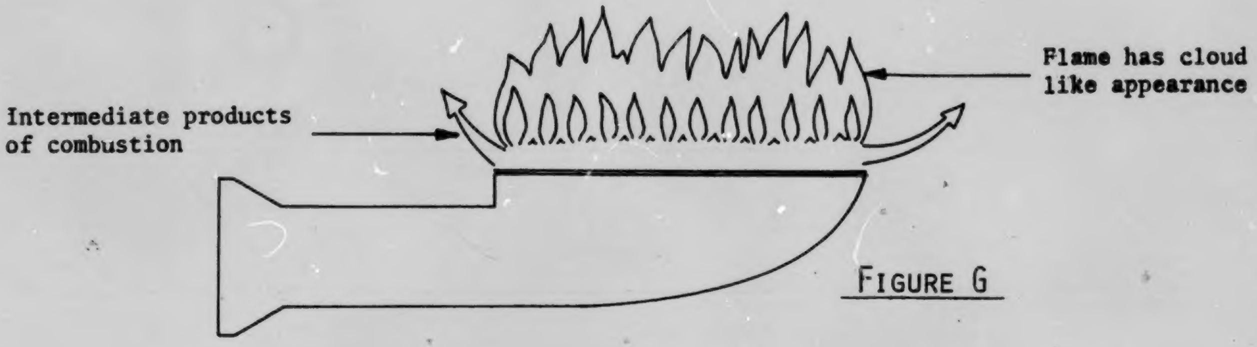

Flame has cloud like appearance
Intermediate products of combustion

FIGURE G

PROCEDURE: See your instructor he will assign you an operating gas furnace. The exact procedure for pulling the burners will vary with different manufacturers. Your instructor will brief you on the exact procedure to be used.

1. Cut off the gas supply.
2. Pull the burners.
3. Clean the burners.
4. Re-install the burners.
5. Operate the furnace.
6. Adjust the primary air, start with the shutter wide open.
7. When you feel you have the proper flame call for an instructor check.

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Inspecting and determining temperature rise of heat exchanger **TIME (est.)** **(act.)**

UNIT NO HE-13

OBJECTIVE(S)

Determine and correct temperature rise of heat exchangers.

START ➡ A-1 W-1 W-2 W-3 W-4 C-1 L-1
C-2

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-13a
W-2 Information Sheet HE-13b
W-3 Information Sheet HE-13c
W-4 Assignment Sheet HE-13a
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-13a
L-2
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-13a
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3
C-4
C-5
C-6
C-7
C-8
C-9

The heat exchanger used in modern gas furnaces evolved from the old fashioned pot belly stove. This old wood or coal burning stove heated a room by natural convection with the products of combustion vented to the outside. Cold air entered from the floor level and picked up heat as it came in contact with outer surface of the stove. The hot air then rises to the ceiling, cools and the cycle repeats itself. Of course the room will also gain some heat from radiation.

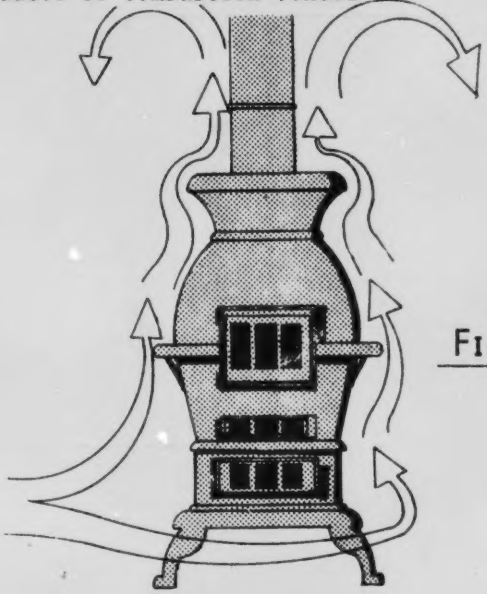
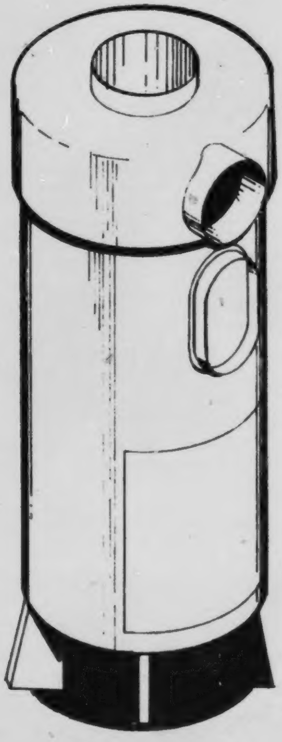


FIGURE A

The modern gas furnace has an opening at the bottom where the burners fit. The opening in the top of the heat exchanger vents the products of combustion. The heat exchanger must be designed to transfer heat to the inside air without allowing the products of combustion to enter. There are flue restrictors located in the heat exchanger which help to control combustion air. The furnace has a blower which circulates inside air across the outer surface of the heat exchanger. This forced convection improves the efficiency of heat exchanger and allows a duct system to be added to direct the heat to all rooms in the house. There are basically two types of heat exchangers in use today. One is the sectionalized exchanger, the other is the barrel exchanger. The barrel looks almost exactly like the old pot belly stove. The burner fits inside and baffles may aid heat transfer to the outer surface. (Figure B).

FIGURE B



The sectionalized heat exchanger (Figure C) has two to six sections depending upon its output (BTUs). There is a burner inside each section which is fed off a common manifold. The blower circulates air outside each section. The sections are curved and dimpled to reduce noise and they may also have a ceramic coating to prevent rust.

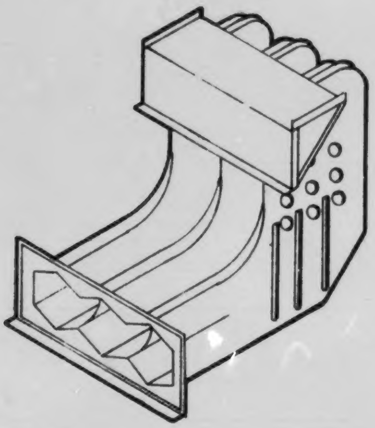
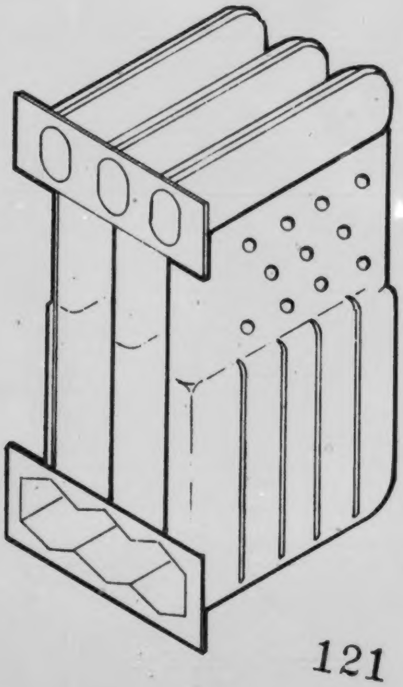


FIGURE C

The heat exchanger used to heat water usually consists of cast iron. The burners fit between the sections similar to the sectionalized heat exchanger mentioned earlier. The sections are called jackets and water is circulated through the jackets by a pump. Other types of water heat exchangers may contain tubes. Again, water is circulated through the tubes with a pump.

Leaks are expensive to repair and the boiler water must be treated with chemicals to prevent corrosion.

FIGURE D



Temperature rise is the amount of temperature rise of the air as it passes across the heat exchanger. For example, air entering the furnace is 70 degrees F, while air leaving the furnace is 140 degrees F. The temperature rise is 70 degrees F.

All furnaces have stamped on the unit nameplate the approved temperature rise for that unit. It will usually be 50 to 70 degrees to 100 degrees rise. A rise higher than normal indicates too little air flow for some reason. Check all things that could reduce airflow before changing fan speed. Some common reasons for reduced air flows are, a dirty filter, dirty fan blades, loose or slipping belt, too many outlets closed off or restricted return air due to insulation inside the duct or unit pulling loose. Higher rise than normal will cause the limit switch to open up. It will also shorten the life of the heat exchanger.

A rise lower than normal is usually caused by the blower running too fast. It could also be caused by the gas pressure being set too low therefore reducing input.

A lower than normal temperature rise may cause condensation of the flue gases which causes rust and shortens heat exchanger life.

By determining temperature rise through the unit and knowing the B.T.U. output, the air delivery can be determined. The cubic feet per minute (CFM) delivery is equal to the furnace output divided by the temperature rise multiplied by 1.08.

The proper method for determing temperature rise is to insert one thermometer in the return duct as near the furnace as possible. Insert another thermometer in the supply duct as near to the furnace as possible. Record these temperatures and determine the difference to find the temperature rise. For best results the house should be near the comfort zone and the furnace should have been running about 15 minutes to warm the duct.

Cracked heat exchangers are caused by improper alignment of the main burners or the pilot burner. When the burners are not in their proper channel, the flame can touch the heat exchanger causing it to overheat. A crack will quickly develop.

Another cause for a cracked heat exchanger is a temperature rise which is too high passing through the heat exchanger for reasons already discussed in Information Sheet HE-13b. Cracks could also develop if the fan switch is improperly set. This could let the heat exchanger overheat before the fan comes on.

Heat exchangers can also fail due to a poorly welded seam from the factory. A crack may be detected by removing the burners and inspecting with a mirror. This may not be necessary however since defects can be detected when the furnace blower blows through the crack disturbing the flame or extinguishing the pilot. Cracks higher up can be detected by pulling the burners and operating the blower while reaching into the burner compartment and feeling for air movement.

1. Explain how a room is heated by natural convection.

2. What is forced convection?

3. There are two general types of heat exchangers, name them.

   1. ______________________

   2. ______________________

4. Where can you find out how much temperature rise a furnace should have?

5. How do you determine temperature rise?

6. What are some things to be checked if temperature rise is too much?

7. What are some things to be checked if temperature rise is too little?

8. What are three things that can cause heat exchanger cracks?

   1. ____________________

   2. ____________________

   3. ____________________

9. What are two symptoms of a cracked heat exchanger?

   1. ____________________

   2. ____________________

10. What is the formula for determining C.F.M. using the temperature rise method.?

PROCEDURE: Your instructor will assign a gas furnace. Operate for 15 minutes then check temperature rise.

1. If there are no holes in the duct, drill two 1/4" holes as near the furnace as possible. One hole in the return duct and another in the supply duct.

2. You will need two properly calibrated thermometers. Insert one in each of the drilled holes.

3. When the thermometers have stabilized record the temperatures.

4. Subtract the return air temperature from the supply air temperature. The result is the temperature rise.

5. Determine CFM (Cubic Feet per Minute) using the temperature rise method.

6. If the temperature rise is too great or too little make the necessary corrections.

7. Ask for an instructor check.

8. Cut the system off and allow it to cool.

9. Pull the burners.

10. Use a mirror to check the heat exchanger for cracks.

11. Ask for an instructor check.

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Venting Heating Systems **TIME (est.)** **(act.)**

UNIT NO HE-14

OBJECTIVE(S)

Make calculations for and install a gas heat venting system.

START ➔ W-1 ▷ W-2 ▷ W-3 ▷ W-4 ▷ C-1 ▷ W-5 ▷ C-2 ▷ W-6 ▷ L-1 ▷ C-3 ▷

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-14a	**A-1**	
W-2	Text Assignment HE-14a	**A-2**	
W-3	Information Sheet HE-14b	**A-3**	
W-4	Assignment Sheet HE-14a	**A-4**	
W-5	Assignment Sheet HE-14b	**A-5**	
W-6	Information Sheet HE-14c	**A-6**	
W-7		**A-7**	
LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-14a	**C-1**	Instructor Check
L-2		**C-2**	Instructor Check
L-3		**C-3**	Instructor Check
L-4		**C-4**	
L-5		**C-5**	
L-6		**C-6**	
L-7		**C-7**	
L-8		**C-8**	
L-9		**C-9**	

The purpose of the venting system is to completely remove all the products of combustion to the outside while preventing condensation or spillage at the draft diverter. The correct amount of air for complete combustion is dependent on heat exchanger design, not on chimney draft.

The heat exchanger is a type of small chimney designed to provide the right amount of combustion air. Baffles are added at the top of the heat exchanger to aid in this process and are usually removable for cleaning. There is a relief device between the heat exchanger and the vent pipe called a draft diverter or draft hood. It is usually a box with an open bottom. (See Figure A).

The purpose of the draft diverter is to provide protection in case of a blocked vent system or temporary downdraft caused by high winds. When this happens the products of combustion "spill" out of the draft hood as shown in Figure B.

If the furnace is located in the house, when spillage occurs the products of combustion enter the house. This is harmless if combustion is complete, however, with incomplete combustion carbon monoxide will enter. This is extremely dangerous and must be corrected immediately.

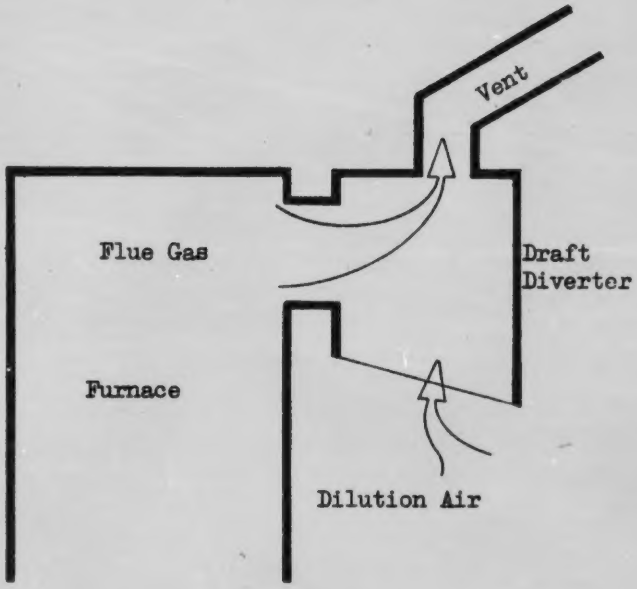


FIGURE A

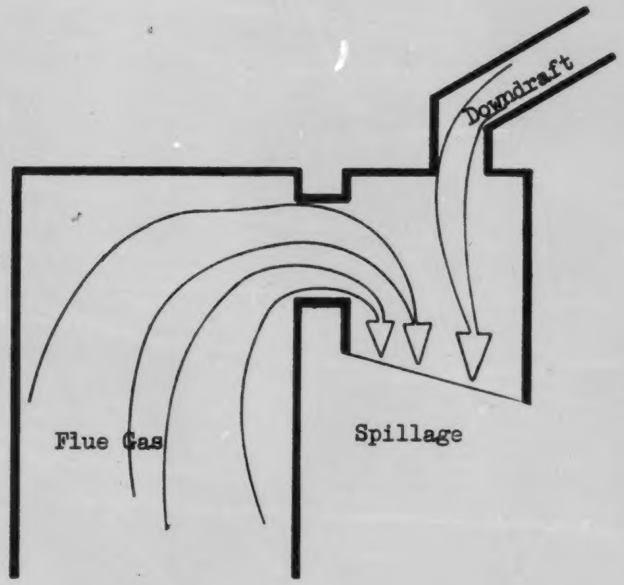


FIGURE B

A check for spillage should be a part of the annual preventive maintenance check. This is a quick easy test, with the furnace operating normally and all doors in place, hold a lighted match, cigarette, or cigarette lighter near the bottom of the draft diverter. If the vent system is operating properly the smoke or flame will be drawn up the draft diverter. If spillage is occurring the smoke or flame will not be pulled up. (See Figure C). Temporary spillage caused by wind gusts are no cause for concern.

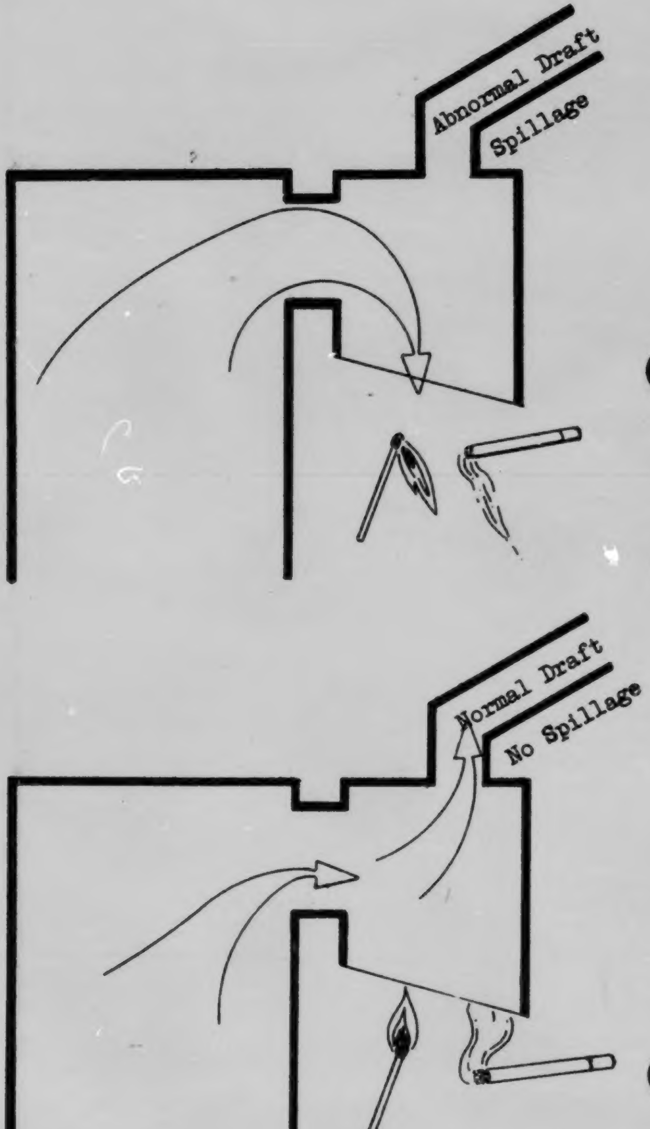


FIGURE C

All appliance and vents must have an adequate air supply for combustion and venting. Each of the combustion grills (input air and output air) must be sized appropriately based on total output of the appliance. The input air grill should be installed low and the output air grill should be installed high. The grills should be installed no closer than three and one-half feet to each other. There are four input-output methods of rating grill size for combustion air:

Method A - Air from inside the building should have no less than one inch free area grill space per 1,000 BTU for each grill.

Method B - Air from outside the building should have no less than one inch free area grill space per 2,000 BTU for each grill.

Method C - Air ventilated from the attic should have no less than one inch free area grill space per 4,000 BTU for each grill.

Method D - Input air coming from basement crawl space and output through the attic should have no less than one inch free area grill space per 4,000 BTU for each grill.

A gas appliance requires 45 cubic feet of air for each 1,000 BTU of rated input. (15 CFM for complete combustion, 15 CFM of dilution air at the draft hood and 15 CFM of ventilation air for control of temperature within the furnace room).

The following example explains how to use the above information to determine cubic feet of combustion air and free area of each grill.

Example:

Condition - a 90,000 BTU furnace receiving all combustion air from inside the building.

a. CFM combustion air ____________ CFM.

b. Free area each grill ______________ sq. in.

CFM combustion air 4050 CFM

45 cubic feet of air for each 1,000 BTU of rated input - 4050 CFM

Free area each grill 90 sq. in.

(Air from inside building)

$$\text{Free area of each grill} = \frac{\text{Total appliance input}}{1{,}000} = \frac{90{,}000\ \text{BTU}}{1{,}000} = 90\ \text{sq. in.}$$

Determine cubic feet of combustion air and free area of each grill for the following conditions. If additional review is needed refer to the reading assignment, Information Sheet HE-14b and the National Fuel Gas Code (1.3.4.3).

1. Condition One: A 100,000 BTU furnace receiving all combustion air from inside the building.

   CFM combustion air ______________________ CFM

   Free area each grill ______________________ sq. in.

2. Condition Two: a 120,000 BTU furnace and a 40,000 BTU water heater receiving all air from outdoors.

   CFM combustion air _______________

   Free area each grill _____________

   Free area each horizontal duct _________________

Individual Venting

Individual venting applys when installing of a single gas appliance is required. To insure that safe conditions are maintained and that the vent system does an efficient job of removing excess gases from the system, it is essential that proper installation be made of venting system. Based on total output of the appliances the specifications for lateral venting, height, and size of vents can be determined from the individual vent table. Excessively long vents should be avoided to prevent excessive cooling and condensation. Vent heights should not be less than five feet (5) from the appliance. When this seems necessary, consult the standard gas codes for minimum vent height requirements.

Allowances for vent size, height, elbows, and lateral runs are provided for in the individual vent table. Use NFPA 54 to answer the following questions. Section 1.5 (1.5.1 through 1.5.9) and Appendix 1-D).

1. Use the individual vent table to determine the vent size for the following installation.

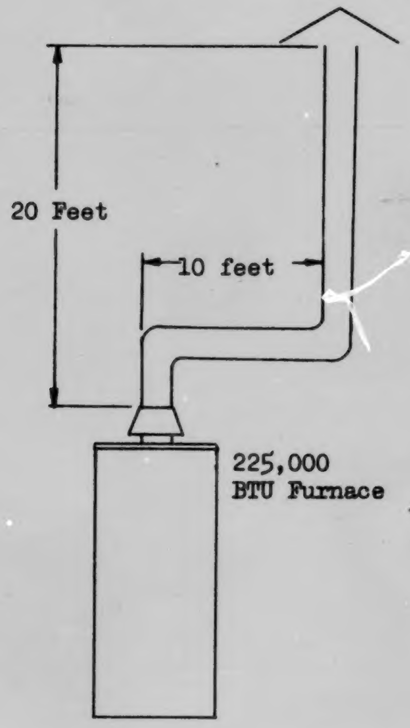


FIGURE D

Combined Venting

A combined venting system is one in which two or more appliances are attached to a common vent. To determine the vent size for a combined venting system it is necessary to use the "Vent Connector Table" and the "Common Vent Table." To use the tables the following characteristics of a combined vent system must be learned.

A. Least Total Height - Vertical distance from the top of the vent to highest appliance.

B. Connector Rise - Vertical distance from one appliance to the point where the second appliance vent connector joins the system.

To determine vent size, each vent connector must be calculated first.

A. Determine the least total height for the system.

B. Determine the connector rise for each appliance.

C. Enter the vent connector table at the appropriate least total height. (1' - 2' - 3') Continue across on the line for the first appliance connector rise to the nameplate BTU rating (or the next higher thing) for that appliance. Read the connector vent size for that appliance at the top of this column.

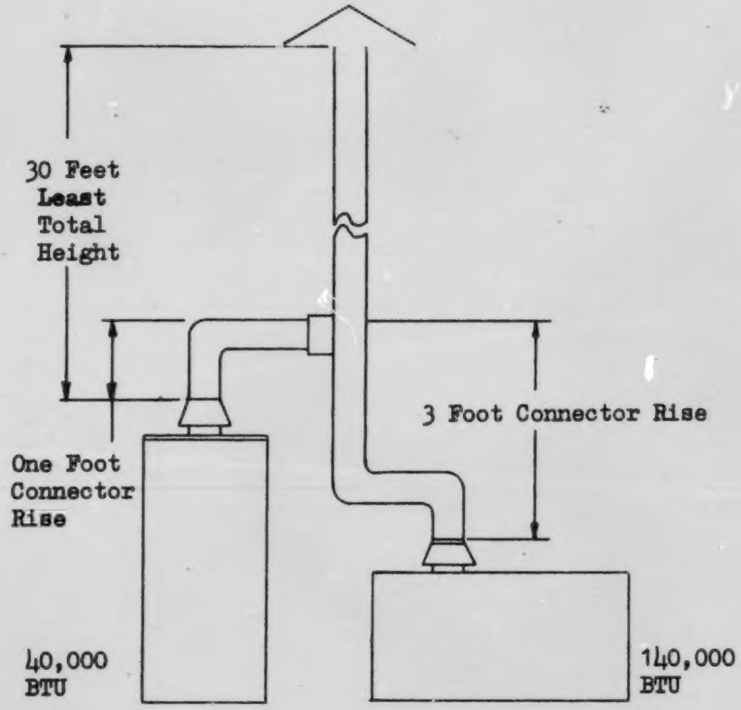
D. At the same least total height repeat the procedure for the connector rise and BTU rating for each appliance.

To determine common vent size:

A. Obtain total BTU ratings of both appliances.

B. Use the Least Total Height, total input, and the appropriate vent type (V for all vertical vent, L if any part of vent is lateral) to determine vent size from the Common Vent Table.

2. Use the combined vent table and common vent table to determine vent sizes for the following system. The least total height is 30 ft. The water heater has a one foot connector rise and the furnace has a 3 ft. connector rise.


30 Feet
Least
Total
Height
3 Foot Connector Rise
One Foot
Connector
Rise
40,000
BTU
140,000
BTU

INDIVIDUAL VENT TABLE

(FOR ONE APPLIANCE ONLY)

TOTAL VENT HEIGHT	LENGTH OF LATERAL	MAXIMUM CAPACITY, Thousands of BTU Per Hour *													
		METALBESTOS VENT SIZE, INCHES													
		3"	4"	5"	6"	7"	8"	10"	12"	14"	16"	18"	20"	22"	24"
5'	0	46	83	133	182	285	345	535	785	1070	1485	1785	2215	2680	3210
	2'	33	82	88	147	283	267	415	600	815	1085	1350	1685	2025	2425
	5'	31	58	85	140	185	256	407	590	800	1050	1340	1665	2015	2420
	10'	28	53	80	131	182	243	380	560	770	1020	1310	1650	1985	2380
6'	0	48	86	141	205	285	370	570	850	1170	1530	1890	2430	2980	3520
	2'	36	67	105	157	217	285	455	650	890	1170	1480	1850	2220	2670
	6'	32	61	100	148	205	273	435	630	870	1150	1470	1820	2210	2650
	12'	28	55	91	137	190	255	400	610	840	1110	1430	1785	2180	2600
8'	0	50	94	155	235	320	415	660	970	1320	1740	2220	2750	3300	4010
	2'	40	75	120	180	247	322	515	745	1020	1340	1700	2110	2560	3050
	8'	35	66	100	165	227	303	490	720	1000	1320	1670	2070	2530	3030
	16'	28	58	96	148	208	281	458	685	950	1280	1600	2035	2470	2960
10'	0	53	100	168	255	345	450	720	1000	1450	1825	2450	3050	3710	4450
	2'	42	81	121	185	273	350	560	850	1130	1460	1860	2340	2840	3390
	10'	38	70	115	173	245	330	525	785	1085	1430	1840	2290	2780	3340
	20'	—	66	108	154	217	300	480	735	1030	1380	1780	2230	2720	3250
15'	0	58	112	187	285	390	525	840	1240	1720	2270	2900	3620	4410	5300
	2'	48	93	150	225	318	414	675	985	1350	1770	2260	2800	3410	4080
	15'	37	78	128	188	275	373	610	905	1250	1675	2150	2700	3300	3980
	30'	—	68	107	180	243	328	553	845	1180	1550	2050	2620	3210	3840
20'	0	61	118	202	307	428	575	930	1350	1900	2520	3250	4080	4980	6000
	2'	51	100	168	248	340	470	755	1100	1520	2000	2570	3200	3910	4700
	10'	44	88	158	228	321	443	710	1045	1460	1940	2500	3130	3830	4600
	20'	35	78	134	205	295	410	685	980	1390	1880	2430	3050	3700	4550
	30'	—	68	128	186	273	380	625	945	1270	1700	2330	2980	3650	4390
30'	0	64	129	220	330	475	650	1000	1550	2170	2820	3770	4750	5850	7080
	2'	58	112	185	290	384	535	865	1310	1800	2380	3000	3810	4650	5600
	20'	—	88	154	237	343	473	784	1185	1650	2200	2870	3650	4480	5310
	40'	—	—	—	200	298	415	705	1075	1520	2060	2700	3400	4270	5140
40'	0	66	132	228	353	500	645	1140	1730	2400	3230	4180	5270	6500	7860
	2'	56	118	188	290	420	578	980	1420	2000	2680	3420	4300	5280	6320
	20'	—	98	167	251	377	518	880	1310	1830	2460	3200	4050	5000	6070
	40'	—	—	—	223	333	480	785	1205	1710	2310	3020	3840	4790	5820
60'	0	—	138	238	373	535	730	1250	1820	2700	3650	4740	6000	7380	9000
	2'	—	125	213	330	470	650	1080	1605	2250	3020	3820	4980	6130	7400
	30'	—	—	170	275	387	555	930	1440	2050	2700	3640	4700	5730	7000
	60'	—	—	—	—	334	475	830	1285	1870	2500	3380	4330	5420	6660
80'	0	—	—	238	384	550	755	1290	2020	2880	3900	5100	6450	8000	9750
	2'	—	—	217	330	495	683	1145	1740	2480	3370	4310	5450	6740	8200
	40'	—	—	—	275	404	570	980	1515	2180	2980	3820	5000	6270	7850
	80'	—	—	—	—	—	—	850	1420	2000	2750	3640	4600	5850	7200
100'	0	—	—	—	400	580	770	1310	2050	2950	4050	5300	6700	8000	10,300
	2'	—	—	—	375	510	700	1170	1820	2550	3500	4600	5800	7200	8800
	50'	—	—	—	—	405	575	1000	1550	2250	3100	4050	5300	6600	8100
	100'	—	—	—	—	—	—	870	1430	2050	2850	3750	4900	6100	7500

NOTES:

A "*" See step 4 of paragraph 1-2.

B "—" Where no capacity is given, vent may be liable to both spillage and condensation.

C Regardless of altitude, always design vent for sea level nameplate appliance input.

D "0" lateral applies only to a vertical vent attached to a top outlet draft hood.

COMBINED VENT TABLES

VENT CONNECTOR TABLE

LEAST TOTAL HEIGHT	CONNECTOR RISE	MAXIMUM INPUT TO VENT CONNECTOR, Thousands of BTU Per Hour													
		METALBESTOS VENT SIZE, INCHES													
		3"	4"	5"	6"	7"	8"	10"	12"	14"	16"	18"	20"	22"	24"
5'	1'	25	44	78	101	137	180	280	404	560	725	917	1136	1372	1635
	2'	30	53	83	120	162	213	333	480	626	817	1035	1277	1545	1840
	3'	33	60	93	135	183	240	375	540	730	850	1175	1450	1755	2080
6'	1'	28	46	72	104	142	185	290	418	577	755	955	1180	1425	1700
	2'	31	55	86	124	168	220	345	486	653	853	1080	1335	1610	1920
	3'	35	62	96	138	188	248	385	556	740	967	1225	1510	1830	2180
8'	1'	27	48	78	109	148	194	303	430	601	805	1015	1255	1520	1810
	2'	32	57	90	129	176	230	358	516	680	910	1150	1420	1720	2050
	3'	36	64	101	145	198	258	402	580	780	1030	1305	1610	1930	2320
10'	1'	29	50	78	113	154	203	314	452	642	840	1080	1310	1585	1900
	2'	33	59	93	134	182	238	372	536	730	965	1205	1480	1800	2150
	3'	37	67	104	150	205	268	417	600	827	1090	1370	1680	2040	2430
15'	1'	30	53	83	120	163	214	333	480	697	910	1150	1420	1720	2050
	2'	35	63	99	142	193	253	394	558	790	1030	1305	1610	1950	2320
	3'	40	71	111	160	218	286	444	640	895	1175	1480	1835	2220	2640
20'	1'	31	56	87	125	171	224	347	500	740	965	1225	1510	1830	2180
	2'	37	66	104	148	202	265	414	590	840	1095	1385	1710	2070	2470
	3'	42	74	116	168	225	300	466	672	952	1245	1575	1945	2350	2800
30'	1'	33	58	93	134	182	238	372	536	805	1050	1330	1645	1990	2370
	2'	39	70	110	158	215	282	438	632	910	1190	1500	1855	2240	2670
	3'	44	78	124	178	242	317	494	712	1035	1350	1710	2110	2550	3040
40'	1'	35	62	97	140	190	248	388	560	850	1110	1405	1735	2100	2500
	2'	41	73	115	166	225	295	461	665	964	1260	1590	1965	2380	2830
	3'	46	83	129	187	253	331	520	740	1100	1435	1820	2240	2710	3230
60'	1'	37	66	104	150	204	266	417	600	920	1210	1530	1880	2290	2720
	2'	44	78	123	178	242	316	494	712	1080	1370	1740	2150	2580	3080
	3'	50	88	138	200	272	355	555	800	1180	1560	1980	2450	2960	3520

COMMON VENT TABLE

LEAST TOTAL HEIGHT	VENT TYPE*	MAXIMUM COMBINED INPUT TO EACH SECTION OF COMMON VENT, Thousands of BTU Per Hour													
		METALBESTOS VENT SIZE, INCHES													
		3"	4"	5"	6"	7"	8"	10"	12"	14"	16"	18"	20"	22"	24"
5'	L	—	48	78	100	148	195	310	455	630	830	1080	1330	1600	1920
	V	—	60	95	137	186	242	383	540	732	982	1240	1530	1815	2205
6'	L	—	52	82	117	160	210	325	468	705	825	1170	1445	1680	2000
	V	—	65	103	147	200	260	410	580	815	1085	1345	1680	1970	2300
8'	L	—	58	91	130	178	230	365	520	782	1035	1310	1620	1820	2330
	V	—	73	114	163	223	290	445	652	912	1190	1510	1880	2290	2600
10'	L	—	63	98	142	183	259	385	560	865	1130	1430	1765	2080	2540
	V	—	78	124	178	242	315	485	712	985	1300	1645	2030	2400	2920
15'	L	—	73	114	164	224	290	460	656	1000	1315	1665	2090	2430	2900
	V	—	91	144	205	280	365	565	825	1150	1510	1910	2380	2780	3400
20'	L	—	81	127	182	250	325	510	728	1128	1470	1860	2300	2720	3310
	V	—	102	160	229	310	405	640	910	1290	1680	2140	2640	3120	3800
30'	L	—	94	147	211	290	375	590	844	1327	1735	2190	2710	3210	3900
	V	—	118	185	266	360	470	740	1025	1525	1990	2520	3110	3680	4480
40'	L	—	105	164	236	320	420	660	945	1482	1950	2470	3050	3610	4390
	V	—	131	203	295	405	525	820	1180	1715	2240	2830	3500	4150	5050
60'	L	—	—	170	250	352	460	720	1100	1750	2280	2900	3570	4230	5050
	V	—	—	224	324	440	575	880	1300	2010	2620	3330	4100	4850	5800
80'	L	—	—	—	275	374	488	785	1222	1950	2590	3230	3900	4720	5730
	V	—	—	—	344	468	610	985	1540	2230	2920	3710	4500	5420	6600
100'	L	—	—	—	—	383	500	790	1335	2140	2790	3530	4300	5100	6250
	V	—	—	—	—	470	625	975	1670	2480	3200	4000	5000	5850	7200

FIGURE F

3. According to National Fuel Gas Code requirements, what is wrong with the vent on this horizontal furnace? (See Figure G).

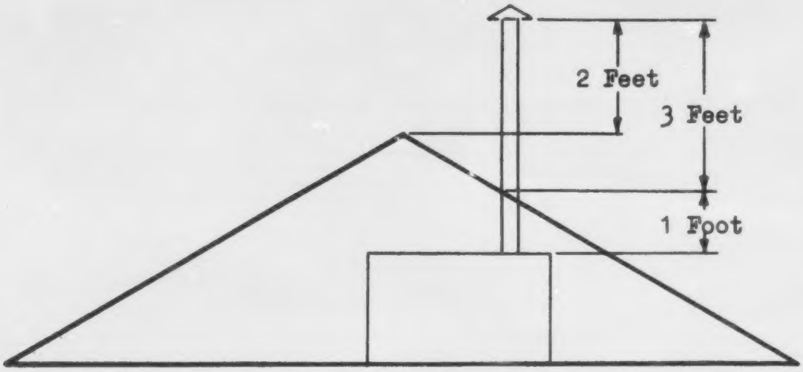


FIGURE G

4. List three (3) appliances on which venting is required. List three appliances on which venting is not required. (According to NFPA 54).

Venting Required	Venting Not Required
1. ______________________	1. ______________________
2. ______________________	2. ______________________
3. ______________________	3. ______________________

5. What is wrong with this combined vent? (See Figure I).

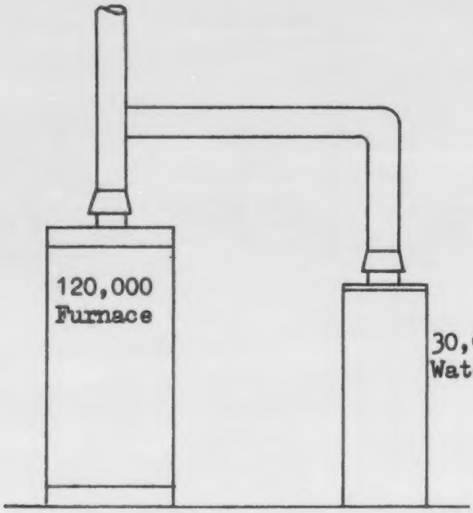


FIGURE I

6. According to NFPA 54, what is a type B gas vent?

7. According to NFPA 54, what type furnace requires a type B-W gas vent?

8. According to NFPA 54, under what conditions can a vent connector be connected to a chimney serving a fireplace?

9. Why must uninsulated outside single wall pipe not be used on appliances with draft hoods in cold climates.

10. How are vent caps sized?

Consider the following points in the design and installation of the flue system:

1. The top of the vent must be at least 2 feet above a horizontal point ten feet from the roof. This helps to prevent downdrafts caused by wind moving across the roof. The top of the vent must be at least two feet higher than the point at which it passes through the roof. (See Figure J).

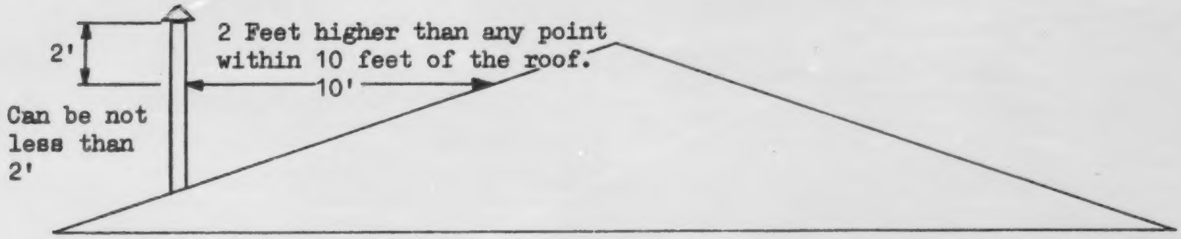

2'
2 Feet higher than any point within 10 feet of the roof.
10'
Can be not less than 2'

FIGURE J

2. The vent pipe must be the same diameter as the vent connection on the furnace. (See Figure K).

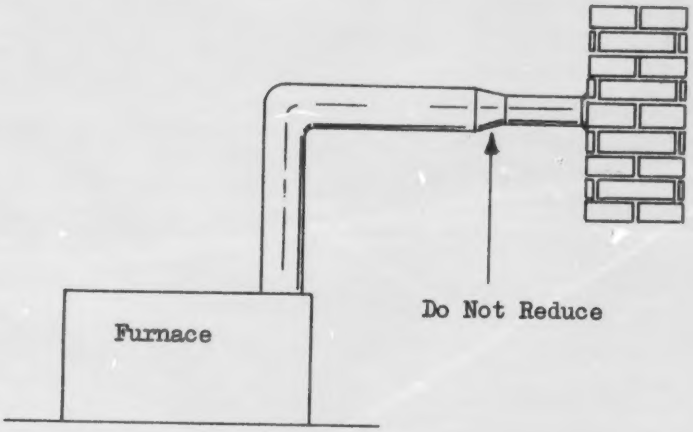

Furnace
Do Not Reduce

FIGURE K

3. Do not extend the vent beyond the inner liner of the chimney. (See Figure L).

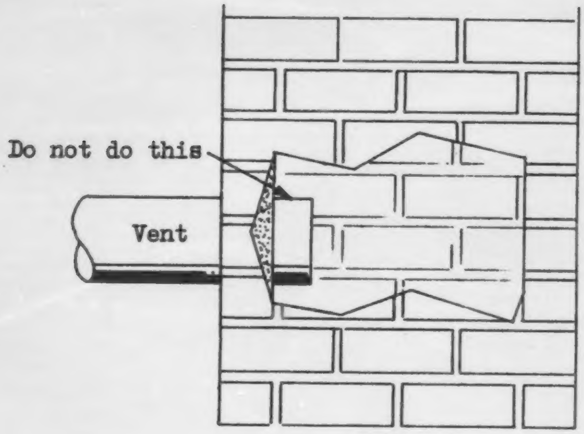


FIGURE L

4. The vent should have as few elbows as possible and horizontal runs should pitch upward a minimum of 1/4 inch per foot and not exceed 10 feet in length. This prevents condensation caused by friction loss and cooling down of flue gas.

5. The vent pipe must be adequately supported, joints should be made in the direction of flow. (See Figure M).

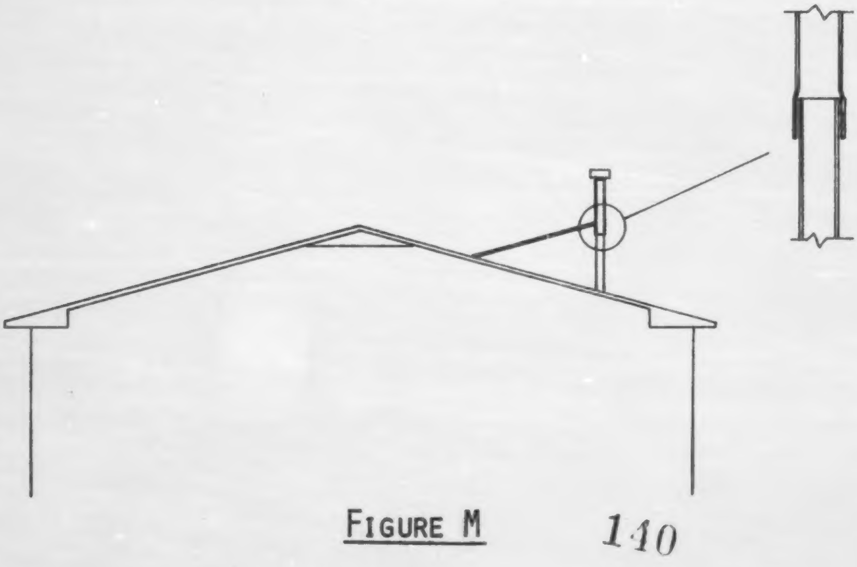


FIGURE M

6. Provide a condensate drip leg in the vertical chimney below the point of entry by the vent pipe. (See Figure N).

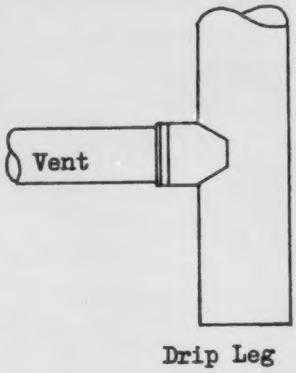


FIGURE N

7. Finally, some common problems with vent systems include such things as bent vent pipe, bent rain cap, bird nests or other debris in the chimney. Also, if the blower door is off the furnace the vent system will not work and all the products of combustion will be drawn into the living area.

1. Use the National Fuel Gas Code and previous activity sheets to calculate and install a vent system on an individually vented gas furnace in the shop.

   A. Record information for the assigned equipment.

      Manufacturer ________________ Serial Number ______________

      Rated Output ________________ BTUs ______________________

      Vent size ____

2. Calculate and install a vent system for two (combined vent) gas appliances in the shop. Record information for the assigned equipment.

   A. Manufacturer ____________________ Serial Number _____________

      Rated Output ____________________ BTUs ______________________

      Vent size ____

   B. Manufacturer ____________________ Serial Number _____________

      Rated Output ____________________ BTUs ______________________

      Vent size ____

MAJOR BLOCK Heating **NAME** ______

TASK Gas Heating Systems

UNIT Servicing Electrical Controls **TIME (est.)** ______ **(act.)** ______

UNIT NO HE-15

OBJECTIVE(S)

Diagnose and service the electrical controls of a gas furnace.

START ➔ W-1 ➔ A-1 ➔ W-2 ➔ W-3 ➔ W-4 ➔ C-1 ➔ L-1 ➔ C-2 ➔ W-5 ➔ L-2 ➔ C-3

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-15a
W-2 Information Sheet HE-15b
W-3 Information Sheet HE-15c
W-4 Assignment Sheet HE-15a
W-5 Text Assignment HE-15a
W-6 ______
W-7 ______

AUDIOVISUAL(S)

A-1 Slide Set HE-15a
A-2 ______
A-3 ______
A-4 ______
A-5 ______
A-6 ______
A-7 ______

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-15a
L-2 Job Sheet HE-15b
L-3 ______
L-4 ______
L-5 ______
L-6 ______
L-7 ______
L-8 ______
L-9 ______

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 ______
C-5 ______
C-6 ______
C-7 ______
C-8 ______
C-9 ______

Some of the information contained in this unit is a review of material from the electrical phase.

When two metals of the same length are bonded together they become a bi-metal strip. Most thermostats use this principle to open and close a switch. In this case the two metals are brass and Invar. The basic operating principle of the bi-metal thermostat is that brass expands and shrinks at a faster rate than Invar. Since brass expands faster it becomes the outside of the curve when heated. When cooled it shrinks faster to become the inside of the curve. (See Figure A).

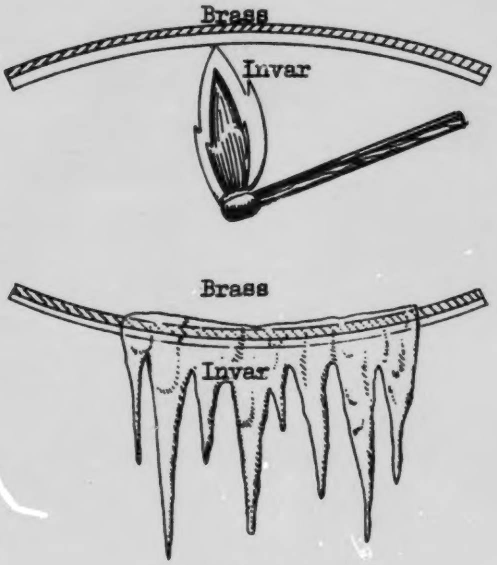


FIGURE A

Figure B illustrates how this principle applies to a bi-metal thermometer. Figure C illustrates how it is applied to open and close switches.

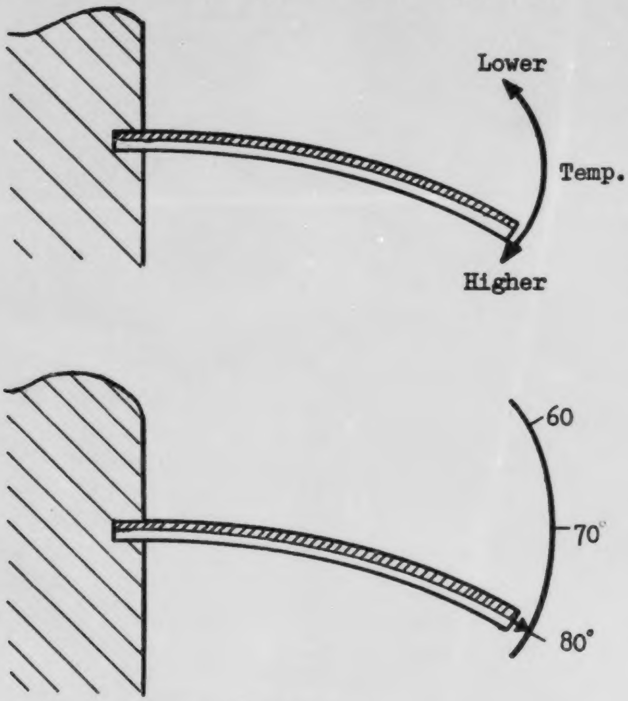


FIGURE B

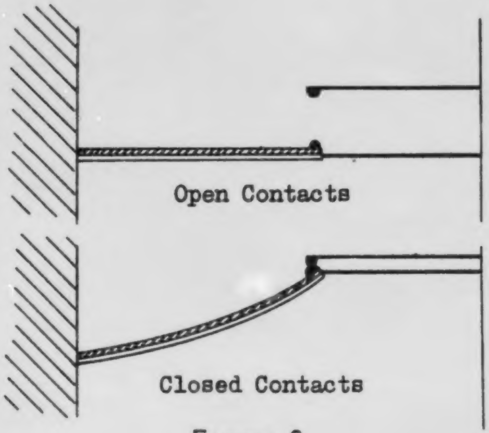


FIGURE C

Figure D illustrates the spiral, disc, and coil bi-metals. The spiral is used on fan and limit switches. One end is anchored and the other end is free to turn a cam which opens or closes the switch. The disc is occasionally used as a secondary limit and as the fan switch and primary limit on wall mounted furnaces. The coil is used in thermometers and in thermostats. The coil is anchored in the center to a moveable lever.

This lever changes the tilt of the coil so that the desired temperature can be set. The sealed glass tube contains electrodes and a drop of mercury. A circuit is made when the mercury moves to the end of the tube which contains the electrodes. Figure E illustrates this in a Heating thermostat.

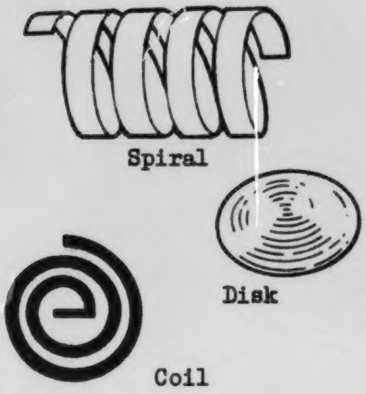
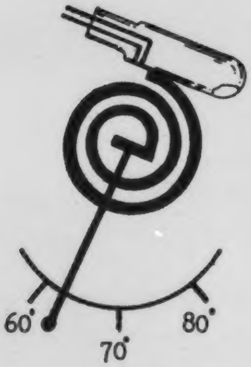


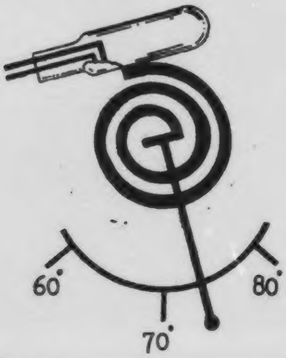
FIGURE D



Lower Temperature Setting

FIGURE E-1

Figure F illustrates how the heat anticipator works. The anticipator is a tiny wire resistor placed near the bi-metal. It is connected electrically in series with the valve or relay that controls the burner. The anticipator is usually adjustable so that it can be set to the current draw of the main valve.



Higher Temperature Setting

FIGURE E-2

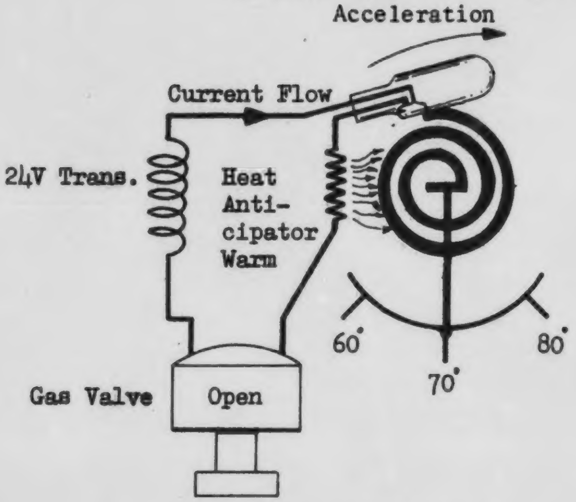


FIGURE F

Anytime the gas valve is energized, heat is added to the thermostat bimetal. This added heat causes the thermostat to cut the burner off slightly before the set room temperature is reached. The furnace fan continues to run, cooling the heat exchanger. When the fan finally cuts off, the room should be within 1 degree of the thermostat setting.

The step down transformer used on gas furnaces provides the 24 volts necessary to operate the 24v main gas valve. The 24 volts are used primarily for reasons of safety. Modern gas furnaces usually have a 24 volt terminal board mounted on or near the transformer to simplify the process of tying the thermostat and condensing unit electrically to the furnace.

The furnace fan usually has a spiral bi-metal switch inserted near the heat exchanger. When the main burner comes on, heat from the burner will cause the spiral to twist closing a set of contacts in the fan motor circuit starting the fan motor. When the main burner cycles off the spiral cools off, opens the switch and stops the fan motor. The High Limit Switch is usually operated by this same bi-metal. If the fan motor should fail to start, the temperature would quickly reach 200 degrees F. which would cause the spiral to further turn the cam and open a switch in the primary or secondary winding of the transformer. Therefore, the main burner would be turned off.

The fan motor is usually a P.S.C. or shaded pole motor. The motors used on direct drive systems have two or three speeds. Larger blowers which require belt drive are usually single speed capacitor start motors.

Details of various electric controls will be viewed in the slide set.

Figure G is an example of a typical fan switch showing the bi-metal helix which is anchored at one end and connected to a shaft at the other end. The shaft turns a cam which closes the fan switch as the temperature rises. The bi-metal is located in the furnace above the heat exchanger so that when the burner is lit, the rise in temperature is felt by the bi-metal. Other models of fan switches may use spiral bi-metal, flat bi-metal, or liquid filled elements.

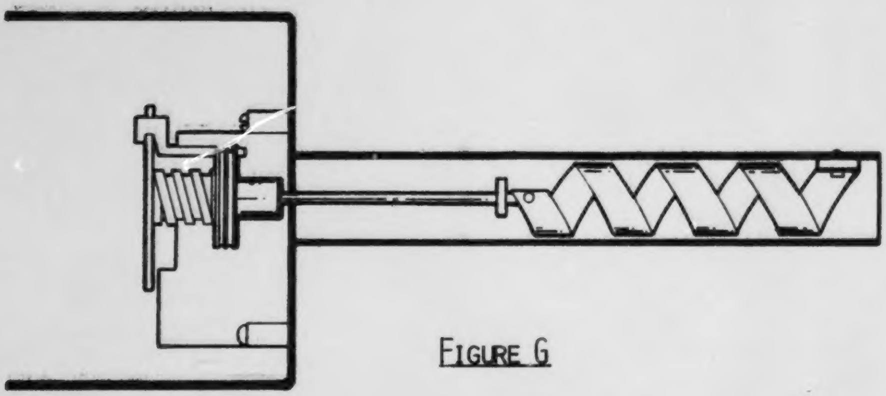


FIGURE G

The fan timer is another type of fan control. It contains a flat bi-metal which is inserted into the furnace. The bi-metal closes a switch in the fan circuit. In addition to the flat bi-metal there is a 24 volt heater element which is energized at the same time as the gas valve. Heat from the furnace or heat from the 24 volt heater will close a switch in the fan motor circuit. Figure H is an example of this type of fan switch. Fan timers are used in place of bi-metal switches inserted into the furnace. They depend entirely on the heat from the 24 volt heater to warp a bi-metal and close the switch. Fan timers may be used on any type furnace but are used primarily on down flow and horizontal furnaces. Some packaged outdoor furnaces also use a fan timer.

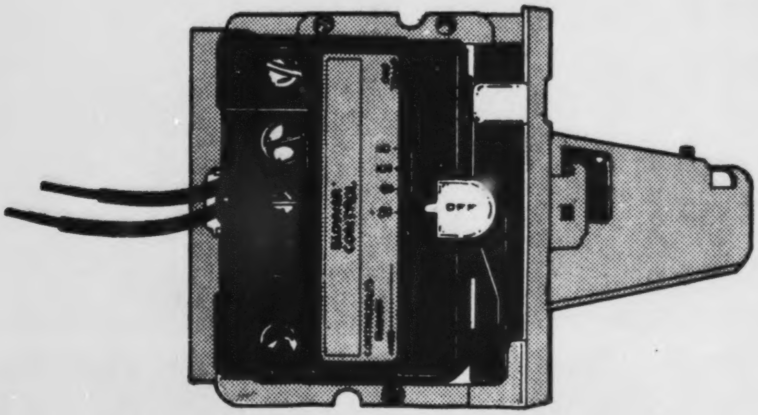


FIGURE H

Fan switches are factory set to engage at about 125 degrees F and disengage at about 100 degrees F. They operate best with a differential setting of 15 to 25 degrees. If the differential setting is set too low (less than 15 degrees) the control will cycle because of slight temperature fluctuations. If set at more than 25 degrees the blower would wait too long before coming on. This will reduce furnace efficiency. Some fan controls have fixed 25 degree differentials, the fan off temperature is adjustable with the on temperature always 25 degrees above the setting. Figure I shows a typical fan switch setting.

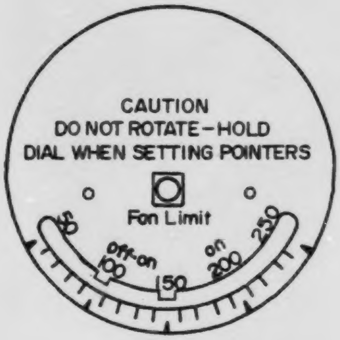

CAUTION
DO NOT ROTATE-HOLD
DIAL WHEN SETTING POINTERS
Fan Limit
50
Off-on
100
150
on
200
250

FIGURE I

The following diagrams describe how the fan switch is wired in the fan motor circuit. Figure J is a simple single speed motor with a fan switch to start the motor as the temperature rises within the heat exchanger.

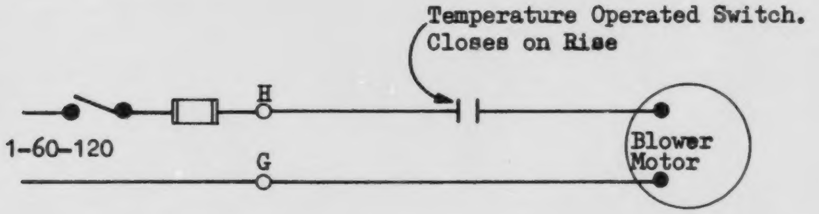

Temperature Operated Switch.
Closes on Rise
H
1-60-120
G
Blower
Motor

FIGURE J

Figure K is a diagram of a two speed fan. This circuit includes a fan relay to activate high speed for cooling.

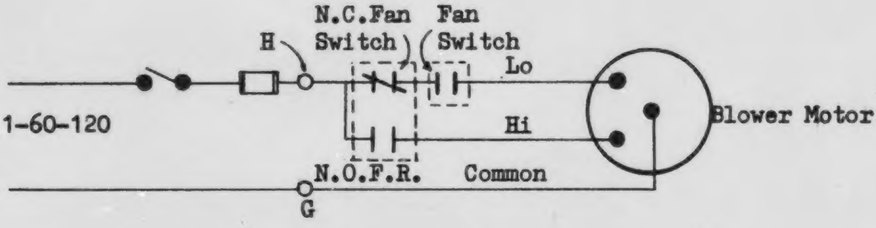

N.C.Fan Switch
Fan Switch
H
Lo
1-60-120
Hi
Blower Motor
N.O.F.R.
Common
G

FIGURE K

Figure L is a diagram of a two speed fan. This circuit includes a transformer, gas valve, and a fan timer switch. The gas valve has a high limit in its circuit. High limits will be covered in more detail later.

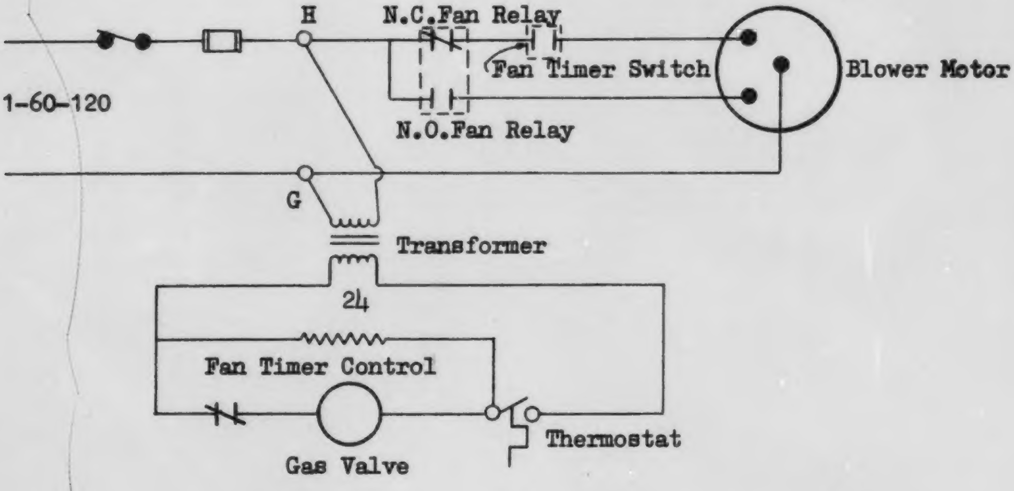

H
N.C.Fan Relay
Fan Timer Switch
Blower Motor
1-60-120
N.O.Fan Relay
G
Transformer
24
Fan Timer Control
Thermostat
Gas Valve

FIGURE L

The thermal high limit switch is the most important safety switch in a furnace. As the name suggests, its purpose is to cut off the gas if the temperature in the furnace plenum exceeds a pre-set temperature. This pre-set temperature is usually 200 degrees F for the primary limit. Secondary limits vary according to their location on the furnace. Primary limits operate on the bi-metal principle just as the fan switch. In fact, the same bi-metal controls both the fan switch and the high limit in most applications. Secondary limits are most often a simple bi-metal disc on which the cut-out temperature is fixed and no adjustment can be made. The secondary limits are located at the furnace blower housing. Secondary limits are most often used on downflow and horizontal furnaces.

Limit switches may be in the primary side of the transformer (line voltage) or in the secondary side (low voltage).

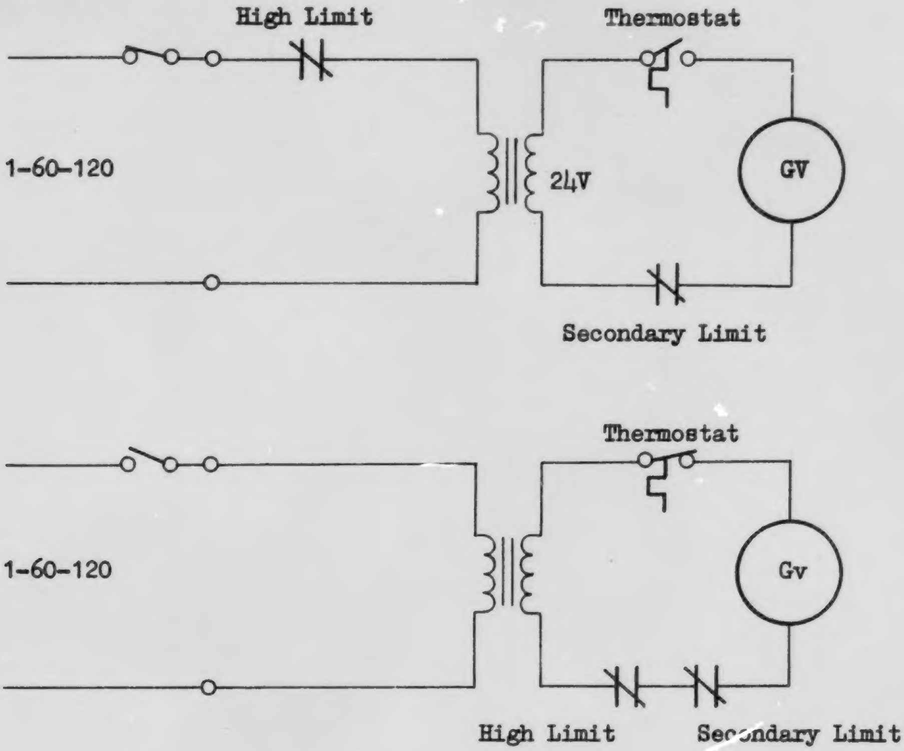

High Limit
Thermostat
1-60-120
24V
GV
Secondary Limit
Thermostat
1-60-120
Gv
High Limit
Secondary Limit

FIGURE M

As stated earlier limits are most often combined with fan switches, they are called combination fan-limit switches. Figure N is a typical example. The arrow on the cam indicates counter clockwise rotation for temperature rise.

FIGURE N-1

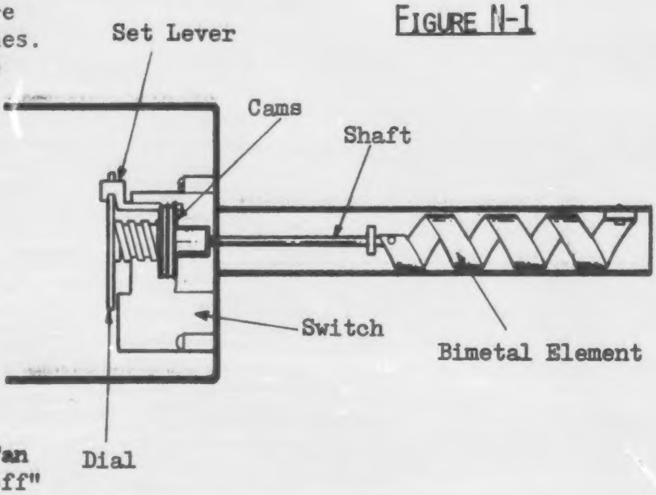

Set Lever
Cams
Shaft
Switch
Bimetal Element
Dial

FIGURE N-2

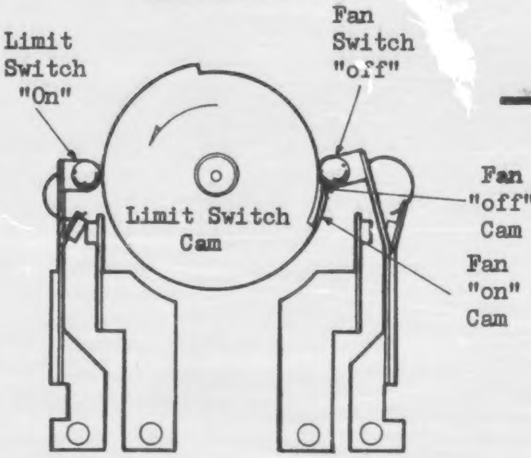

Limit Switch "On"
Fan Switch "off"
Limit Switch Cam
Fan "off" Cam
Fan "on" Cam

Figure O is a typical dial of a combination fan-limit switch. If the homeowner desires continuous air circulation, set the fan "off temperature" below the normal return air temperature. In this way, the air passing over the heat exchanger will always be above the off setting and even though the burners are off the fan will continue to run.

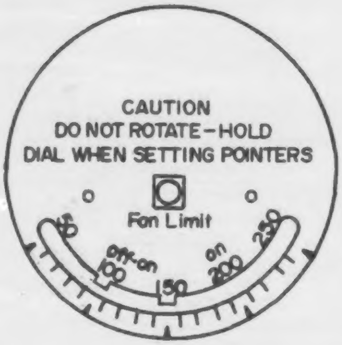

CAUTION
DO NOT ROTATE-HOLD
DIAL WHEN SETTING POINTERS
Fan Limit
50
off-on
100
150
on
200
250

FIGURE O

If a furnace cycles on the limit, the most likely cause is low air movement. Do not raise the setting of a limit, rather, find the cause for the low air movement. The most common cause is dirty air filters or dirty fan blades.

Figure P illustrates a combination fan-limit switch with the limit in the primary side of the transformer. The secondary limit is the low voltage circuit.

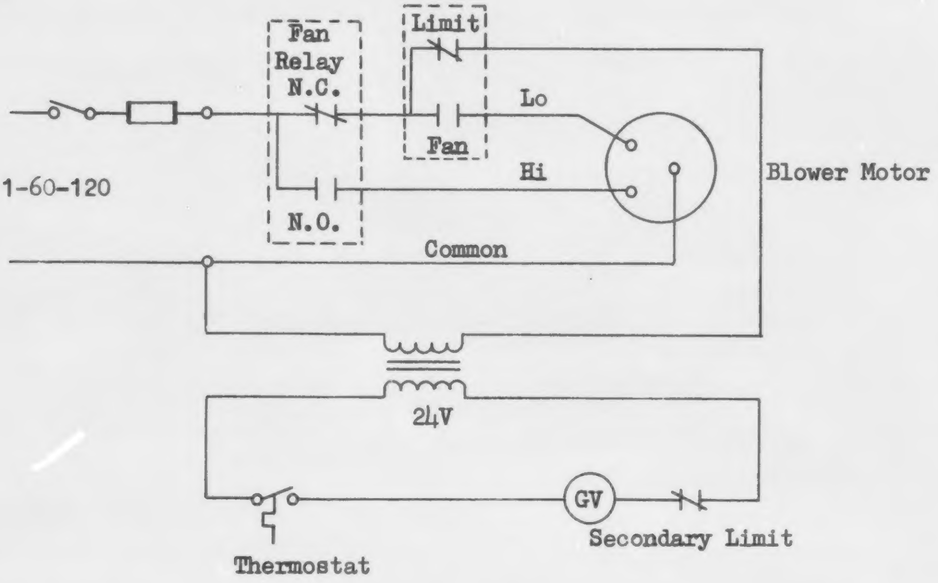

Fan
Relay
N.C.
N.O.
Limit
Fan
Lo
Hi
Blower Motor
1-60-120
Common
24V
GV
Thermostat
Secondary Limit

FIGURE P

Figure Q illustrates a combination fan-limit switch with the limit in the secondary of the transformer.

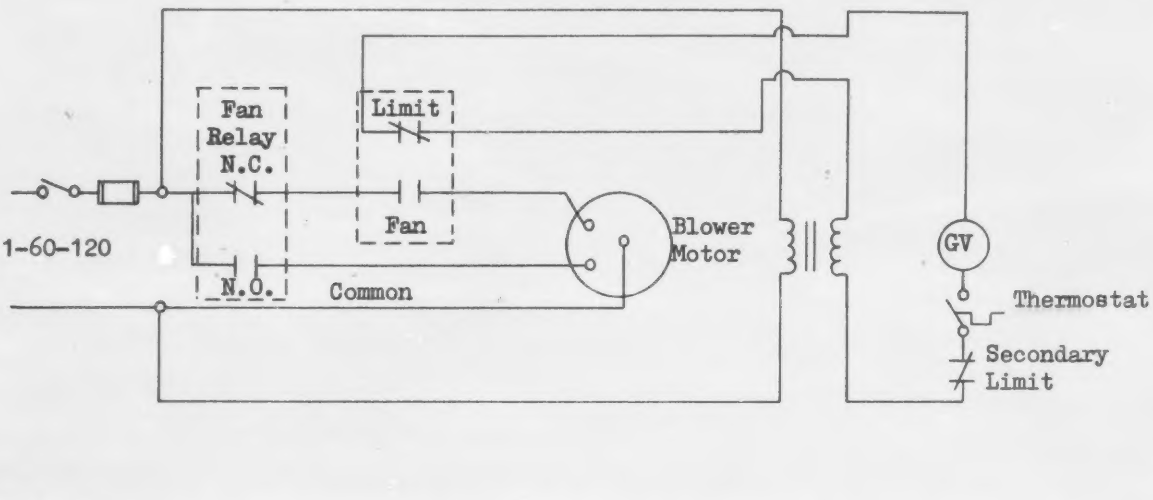

Fan
Relay
N.C.
N.O.
Limit
Fan
Blower
Motor
1-60-120
Common
GV
Thermostat
Secondary
Limit

FIGURE Q

Assignment Sheet HE-15a

The following two diagrams are identical. Draw the circuit in R-1 with the limit in the line side, and R-2 with the limit in the low voltage side. Make your line voltage connections in the furnace junction box.

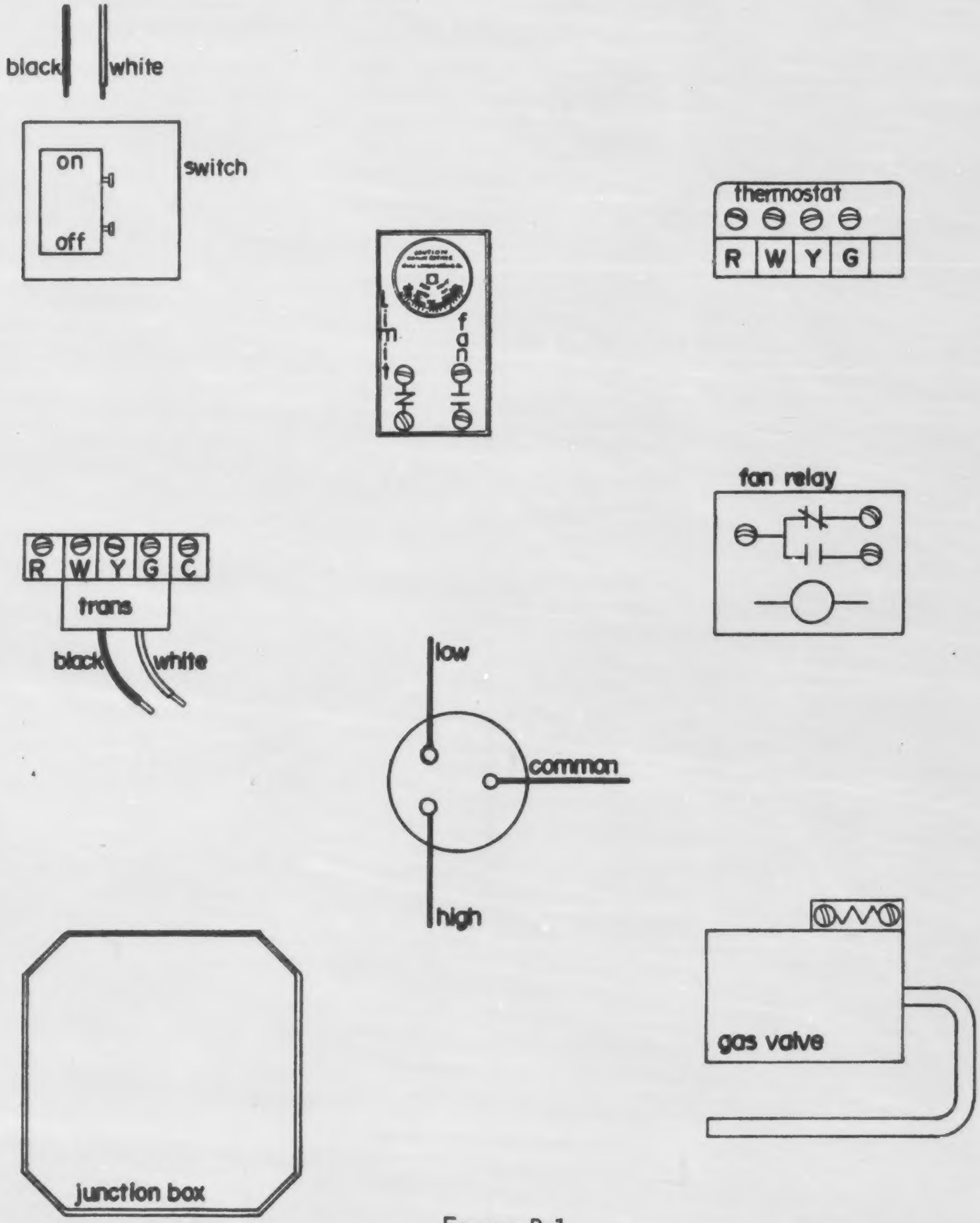

black
white
on
off
switch
limit
fan
thermostat
R
W
Y
G
fan relay
R
W
Y
G
C
trans
black
white
low
common
high
gas valve
junction box

FIGURE R-1

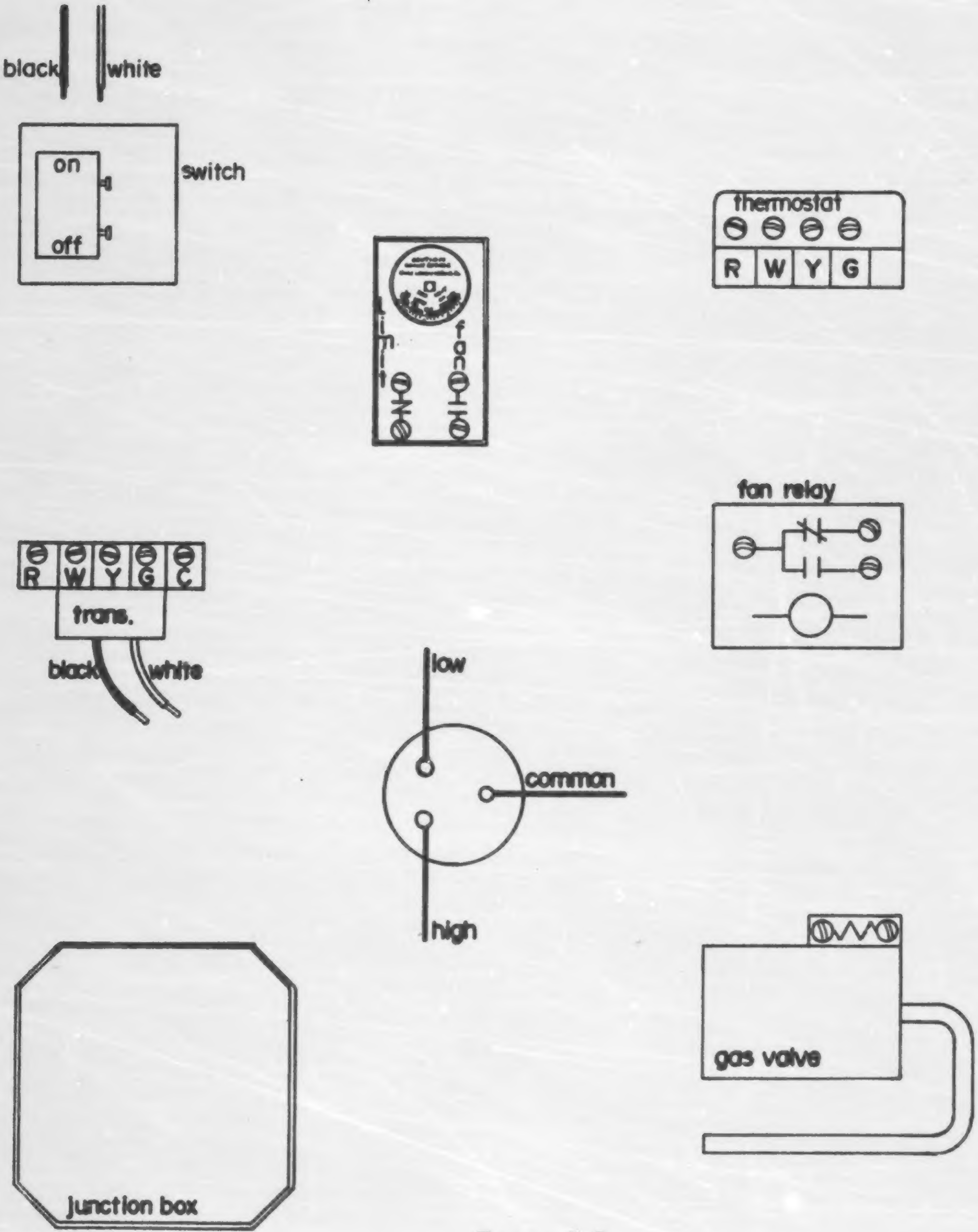

black
white
switch
on
off
thermostat
R
W
Y
G
limit
fan
fan relay
R
W
Y
G
C
trans.
black
white
low
common
high
gas valve
junction box

FIGURE R-2

Procedure:

A. Fill out the data sheet below on two assigned gas furnaces.

Unit 1	Unit 2
Unit make _______	Unit make _______
BTU input _______	BTU input _______
BTU output ______	BTU output ______
Voltage _________	Voltage _________
Amps-gas valve _____	Amps-gas valve _____
Fan-limit combination ____	Fan-limit combination ____
separate _______	separate _______
Limit line voltage _______	Limit line voltage _______
low voltage ________	low voltage ________
Limit setting __________	Limit setting __________
Fan on temp ______	Fan on temp ______
off temp _____	off temp _____
Unit temp rise ____________	Unit temp rise ____________

B. Tape two thirds or three fourths of the burner orifices. Operate the furnace, observe the fan switch.

C. Unplug the fan relay or otherwise disconnect the fan motor. Operate the furnace. Observe operation. When the burner goes out restart the fan. When the burner comes back on, cut it off at the thermostat and allow the heat exchanger to cool.

D. Set the fan "on temperature" at 90 degrees, operate for 10 minutes and record the temperature rise. ______

E. Set the fan "on temperature" at 150 degrees, operate for 10 minutes and record the temperature rise. ______

F. Set the fan "off temperature" at 50 degrees and the "on temperature" at 75 degrees. Operate the unit for 5 minutes, cut it off at the thermostat and wait 5 minutes. Observe the fan operation.

G. Return fan switch to original settings.

Procedure: Your instructor will assign you to a gas furnace having forced combustion. Most residential gas-paks or roof top units will use a blower to provide combustion air. Use the manufacturers service manual as a troubleshooting guide. The instructor will create problems to be solved in several of the following areas.

	Check Here If Operational	Diagnosis
A. Direct spark or pilot ignition device		
B. Combustion blower or blower relay		
C. Sail switch or air pressure switch		
D. Fan switch		
E. Limit switch		
F. Gas pressure		
G. Secondary limit		
H. Thermostat or heat anticipator		

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Determining Combuston Efficiency **TIME (est.)** ____ **(act.)** ____

UNIT NO HE-16

OBJECTIVE(S)

Determine the combustion efficiency in a gas heating system.

START ➔ W-1 A-1 W-2 C-1 L-1 C-2

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Information Sheet HE-16a	A-1	Slide Set HE-16a
W-2	Assignment Sheet HE-16a	A-2	
W-3		A-3	
W-4		A-4	
W-5		A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Job Sheet HE-16a	C-1	Instructor Check
L-2		C-2	Instructor Check
L-3		C-3	
L-4		C-4	
L-5		C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

The flue gas temperature and the percent of CO_2 (carbon dioxide) in the flue gas determines the percentage of combustion efficiency. Combustion efficiency is an indication of the useful heat obtained from the fuel.

Carbon dioxide is a product of combustion. When natural gas is burned with no excess air 11.7 percent of the volume of the flue gas will be CO_2. The ultimate CO_2 content for natural gas is 11.7 percent.

American Gas Association codes and local codes prohibit the use of furnace designs which would ultimately produce CO_2. A furnace must be designed to provide excess combustion air. The introduction of excess combustion air reduces the percent by volume of CO_2 in the flue gas and reduces the possibility of producing carbon monoxide (CO).

Most furnace manufacturers design their furnaces to provide for 66 to 75 percent of the ultimate. This is accomplished by the addition of flue gas restrictors in the heat exchanger. Keeping this in mind expect a CO_2 level of 7 to 9 percent in natural gas furnaces. High CO_2 levels are caused by a lack of combustion air or overfiring the burners. Overfiring is caused by high gas pressure or an oversize orifice. The percentage of CO_2 in the flue gas is easily determined using the Fyrite combustion efficiency test kit. The following is a brief description of how the kit is used. Fyrite instructions 10-F-5i will be available to you when performing the combustion efficiency test.

There are four basic steps in measuring CO_2 level:

1. Adjust zero percent scale mark to the top of the fluid column in the small central bore.

2. Pump flue gas sample into the Fyrite.

3. Absorb CO_2 from sample in Fyrite with Fyrite fluid.

4. Read percent of CO_2 on Fyrite scale at the top of the fluid column.

To adjust to zero invert the Fyrite until all the fluid is in the top, then turn the Fyrite back over holding it at a 45^o angle for 5 seconds. Holding the Fyrite upright depress the plunger valve, venting into the atmosphere, next, release the plunger. Loosen the knob holding the scale in place and line up zero percent with the top of the Fyrite fluid in the column. Now tighten the scale lock knob. To pump the flue gas sample into the Fyrite insert the metal end into the vent where the flue gases are. Hold the rubber connector tip, which is the opposite end of the tube with the metal end, down against the plunger valve. Depress the plunger valve with the connector tip and squeeze and release the aspirator bulb 18 times. Immediately after the 18th squeeze release the connector tip and plunger valve. This traps the flue gas sample in the Fyrite.

In order for the sample to be absorbed into the fluid invert the Fyrite as before. Do this two times, each time holding at a 45° angle until the fluid has drained into the bottom. Now hold the Fyrite level and read the top of the column. This is the amount of CO_2 in this sample. To check the fluid strength repeat the test immediately. An increase of more than 1/2% CO_2 in the second reading over the first reading indicates a need for fluid replacement. The Fyrite fluid should remain accurate for 400 samples.

The amount of excess air required for safe heating unit operation cannot be stated specifically because most units have considerable tolerances. Central furnaces or gas water heaters may range from 25-50% while a gas space heater may range from 50-100%. Unless otherwise stated by a specific appliance a CO_2 reading of 7 to 9 percent should be expected which insures excess air in the range of 66 to 75 percent of the ultimate. This applies to gas furnaces or boilers.

Using the Fyrite fire efficiency finder from the Bacharach CO_2 analyzer answer the following questions. All of these questions apply to natural gas.

1. The stack temperature measures 320 degrees F. The furnace room temperature is 70 degrees F. The CO_2 reading is 8%. What is the combustion efficiency? What is the stack loss?

2. The stack temperature is 500 degrees F. The furnace room temperature is 75 degrees F. The CO_2 reading is 7.5%. What is the combustion efficiency? What is the stack loss?

3. The stack temperature is 580 degrees F. The room temperature is 70 degrees F. The CO_2 reading is 9 percent. What is the combustion efficiency? What is the stack loss?

4. You have just checked the CO_2 and it is 7.5 percent. Your foreman wants to see it so you check again and it checks out 8.5 percent. What is the problem?

Job Sheet HE-16a

Procedure: Obtain the Fyrite combustion kit from the instrument cabinet. You will perform combustion efficiency test on two assigned gas furnaces in the lab.

Unit #1
Stack temperature __________ Make ____________
Room temperature __________ Model No. ________
Net stack temperature __________
CO_2 percentage __________
CO percentage __________
O_2 percentage __________
Draft __________

Unit #2
Stack temperature __________ Make ___________
Room temperature __________ Model No. ______
Net stack temperature __________
CO_2 percentage __________
CO percentage __________
O_2 percentage __________
Draft __________

MAJOR BLOCK HEATING **NAME**

TASK Gas Heating Systems

UNIT Performing a pre-season check **TIME (est.)** **(act.)**

UNIT NO HE-17

OBJECTIVE(S)

Perform a pre-season check on a gas heating system

START ➡ W-1 → W-2 → A-1 → W-3 → C-1 → L-1 → C-2

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-17a
W-2 Text Assignment HE-17a
W-3 Assignment Sheet HE-17a
W-4
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-17a
L-2
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-17a
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3
C-4
C-5
C-6
C-7
C-8
C-9

INTRODUCTION TO PREVENTIVE MAINTENANCE

Many times a homeowner asks for a pre-season check of a furnace; the service technician comes out and lights the pilot, changes the filter, checks the belt, oils the motor, turns the thermostat up, and checks the burner operation. The technician assures the homeowner that they are set for the winter and everything is satisfactory.

While the above check does assure that the furnace will operate it does not assure safe operation. The following is a list of the recommended items to be checked on a gas furnace:

1. Inspect flue pipe and draft diverter.
2. Inspect air filters - change if necessary.
3. Check blower belt wear, alignment, tension.
4. Check blower motor lubricate.
5. Check blower for cleanliness - recommend removal and cleaning if necessary.
6. Check fan switch setting and operation.
7. Test for gas leaks (soap bubbles).
8. Test and adjust pressure regulator.
9. Lubricate all necessary parts.
10. Clean and adjust pilot assembly.
11. Clean and adjust all controls.
12. Check operation of limit switch.
13. Check heat exchanger and vent system for leaks.
14. Clean interior of vestibule or manifold compartment.
15. Clean and adjust thermostat, if necessary.
16. Adjust burner for efficiency (set primary air).
17. Check gas valve operation.
18. Check furnace operation (complete cycle).
19. Inspect furnace wiring for cracked insulation or loose connection.
20. Check for combustible materials near furnace.
21. Apply service sticker and recommend any needed repairs to homeowner.

Various furnace manufacturers will usually have their own check list. The checklist furnished on the preceding page is a general one not supplied by any particular manufacturer. Hopefully, the checklist will help the student realize that a pre-season check is serious business. The homeowner has placed all his trust in the service technician to assure safe and econominal operation of the furnace. MAKE A COMPLETE CHECK!

Often the consumer will call a service technician only when the furnace fails to operate. After eight or ten years service will be needed for problems related to thermocouples or fan motors, etc. When a call of this nature is received, repair the furnace and explain the importance of complete safety and preventive maintenance checks on a regular basis.

Use this paper to develop a list of the things that should be included in a complete operational and safety check of a gas furnace. Your instructor must approve this check list before you continue.

Job Sheet HE-17a

Your instructor will provide a working gas furance to perform a pre-season start up. Use the following check sheet to perform the activity.

Typical Check Sheet

"Gas-Fired Heating Units"

Dealer Name ____________________

Address ____________________

Homeowner's Name ____________________

Address ____________________

Date ____________ Man ____________ Time In ________ Time Out ________

Furnace Make and Model ____________________

Comments by Homeowner ____________________

____

____

AT THERMOSTAT

- ____ Record thermostat set point ____
- ____ Check thermostat for dust or dirt and level
- ____ Turn thermostat to "highest" setting

AT FURNACE

- ____ Check supply voltage and record Time_____ Voltage ________
- ____ Clean or change filters
- ____ Clean out blower wheel and blower compartment

BELT -DRIVE BLOWERS

- ____ Check all wiring in blower compartment for loose connections or bad insulation
- ____ Remove blower belt and check for wear
- ____ Check blower and motor bearings
- ____ Check pulley and drive alignment
- ____ Check motor brackets for tightness
- ____ Check pulley and drive set-screws for tightness
- ____ Check blower for free operation
- ____ Lubricate blower and motor bearings, Prepare furance for tests to follow
- ____ Check Limit Control operation (while blower belt is off)
- ____ Put belt back on blower and drive pulleys and check tension and slippage
- ____ Check temperature rise Record ________

DIRECT-DRIVE BLOWERS

- ____ Check all wiring in blower cabinet for loose connections and bad insulation
- ____ Check motor bearings
- ____ Check for free blower operation
- ____ Check blower set screws for tightness
- ____ Lubricate motor bearings
- ____ Check Limit ("Disconnect" blower motor from electrical source.)
- ____ Check temperature rise, Record ____

IN COMBUSTION VESTIBULE

- ____ Check all electrical wiring for loose connections and damaged insulation
- ____ Check burners for lint, dust and scale.
- ____ Clean if required
- ____ Check pilot flame
- ____ Check thermocouple millivoltage, (record under load and open circuit)
- ____ Check safety drop out time (maximum 2-1/2 minutes).
- ____ Check manifold gas pressure. Adjust if required
- ____ Check control circuit amp-draw and re-adjust heat anticipator setting if required
- ____ Check draft diverter
- ____ Check humidifier

AT THERMOSTAT

- ____ Check heat anticipator setting
- ____ Set thermostat dial to the set-point recorded at the beginning of this service call

MAJOR BLOCK Heating **NAME**

TASK Gas Heating Systems

UNIT Troubleshooting the heating system **TIME (est.)** **(act.)**

UNIT NO HE-18

OBJECTIVE(S)

Locate, diagnose and repair combustion and electrical problems in gas furnaces.

START ➡ W-1 C-1 L-1

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-18a
W-2
W-3
W-4
W-5
W-6
W-7

AUDIOVISUAL(S)

A-1
A-2
A-3
A-4
A-5
A-6
A-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-18a
L-2
L-3
L-4
L-5
L-6
L-7
L-8
L-9

CHECKPOINT(S)

C-1 Instructor Check
C-2
C-3
C-4
C-5
C-6
C-7
C-8
C-9

In the previous units on gas heating systems detailed information has been given on all the components of gas furnaces and gas distribution systems. This information sheet will review some common problems encountered with gas heating and some possible solutions.

Filters

The number one problem is air movement or the lack of it caused either by dirty filters or the removal of filters from the system. A forced air system must be filtered. Without a filter dust will adhere to the blower, motor, and duct work. If the unit has a cooling coil it will become clogged with dust extremely fast under poor filtering conditions. Metal filters are not recommended because of their higher resistance to air flow. Also, when washed, lint from the air will tend to pack in the filter and further restrict air flow. The throwaway filter is the best and usually the most frequently recommended filter. It is treated with a light oil to improve efficiency and when changed on a regular basis it will keep the entire air handling system clean.

Pilot Problems

Pilot problems are the second most frequent cause of heating problems:

1. The pilot does not burn normally. It does not light or stay lit. Look for a clogged pilot orifice, clogged pilot line or pilot filter.

2. The pilot lights but goes out when the reset button is released. If the pilot is enveloping the thermocouple the proper 3/8 to 1/2 inch look for a bad thermocouple or bad millivoltage solenoid. Also a loose or dirty connection of the thermocouple may exist at the cold junction.

3. If the pilot flame does not envelop the thermocouple properly--look at the flame itself. A large yellow flame is caused by a restricted primary air opening or a pilot orifice that is too small. A wavering blue flame is caused by an excessive draft at the pilot location. The pilot may not be mounted properly or is being drawn away from the thermocouple by excessive draft of the main burner. A small blue flame caused by too small orifice, low gas pressure or partially clogged orifice. A noisy lifting flame caused by high gas pressure may be apparent.

If the pilot is operational but the main gas valve does not operate check for the following problems:

1. Start with a primary voltage check; look for blown fuses, loose connections, burned wires or open high limit switch.

2. If primary voltage is sufficient, check the secondary side of the transformer. If an open secondary winding is found look for a shorted load or shorted wires on the 24 volt circuit. Check thermostat contacts for dust, loose connections or, loose wires.

3. If 24 volts is measured at the valve terminals check for an open coil in the valve, sticking valve, or clogged internal gas ports.

There are other problems which can relate to a faulty ignition. An example would be delayed ignition which could be caused by a small pilot flame, improperly positioned pilot valve or misalignment of the burners and pilot runner. Flash back or burning on the spud is caused by insufficient primary air, low gas pressure or damaged burner inserts.

Complaints of insufficient heat range can be traced to various problems which could include anything from an undersized furnace to a thermostat out of calibration. Other possibilities include low gas pressure, poor thermostat location, and cycling on the limit which is caused by low air movement.

A complaint of too much heat could be caused by many things including a thermostat location, a thermostat out of calibration, a short between R & W wires from the thermostat or the main gas valve stuck open. Complaints of soot or fumes will call for a complete check of the heat exchanger, primary and secondary air and vent systems.

Job Sheet He-18a

Procedure: Locate combustion and electrical problems in two operating gas furnaces in the lab. When completed the instructor must check off each of the areas below.

Combustion Problems	SATISFACTORY	UNSATISFACTORY
Leaks	______	______
Gas valve problems	______	______
Gas pressure problems	______	______
Ignition or flame problems	______	______
Vent problems	______	______
Electrical Problems		
Control circuit problems	______	______
Transformer problems	______	______
Fan switch problems	______	______
*Limit switch problems	______	______
Fan motor problems	______	______

*May involve air movement problems

MAJOR BLOCK Heating **NAME**

TASK Oil Burning Systems

UNIT Identifying Types of Fuel Oil and Principles of Combustion **TIME (est.)** **(act.)**

UNIT NO. HE-19

OBJECTIVE(S)

Be able to identify different grades of fuel oil.

START ➡ W-1 W-2 W-3 C-1

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-19a	**A-1**	
W-2	Text Assignment HE-19a	**A-2**	
W-3	Assignment Sheet HE-19a	**A-3**	
W-4		**A-4**	
W-5		**A-5**	
W-6		**A-6**	
W-7		**A-7**	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1		**C-1**	Instructor Check
L-2		**C-2**	
L-3		**C-3**	
L-4		**C-4**	
L-5		**C-5**	
L-6		**C-6**	
L-7		**C-7**	
L-8		**C-8**	
L-9		**C-9**	

Historically, fuel used for heating was a solid type fuel such as wood or coal and was burned in a fire place, stove, or boiler; but it produced an ash that had to be removed every day or so. Also, the wood and coal had to be brought in by hand.

In later years, liquid gaseous fuels were discovered and used in our modern central heating systems which are fully automatic and eliminated the handling of solid fuels and ash. Central heating systems today produce heat through the process of combustion which involves combining oxygen with gas or oil and ignited by a spark or flame.

There are six (6) grades of fuel oil in use today. Some grades of oil will burn quite readily at room temperature while others are heavier and must be heated. (See Figure A).

Grade	Description	BTU per gallon	Uses	Approximate Weight	Flash Point Minimum °F	Pour Point Maximum °F
No. 1	A distillate oil intended for vaporizing in pot-type burners and in other burners requiring this grade. (kerosene)	132,900 to 137,000	Pot-type Burners	6.95	100 or legal	0
No. 2	A distillate oil for general-purpose domestic heating for use in burners not requiring No. 1.	135,800 to 141,800	Domestic Heating Equipment	7.29	100 or legal	20
No. 4	Preheating is not usually required for handling or burning.	143,100 to 148,100	Industrial Heating Power	7.78	130 or legal	20
No. 5	(Light) preheating may be required for handling depending on climate and equipment.	146,800 to 150,000	Industrial Heating Power	7.94	130 or legal	
No. 5	(Heavy) preheating required for burning, and in cold climates heating may be required for handling.	149,400 to 152,000	Industrial Heating Power	8.08	130 or legal	
No. 6	Preheating required for burning and handling.	151,300 to 155,900	Industrial Heating Power	8.44	150	

FIGURE A

There are a number of characteristics that determine the grade of fuel oil:

1. Viscosity - thickness of oil or measuring its resistance to flow.
2. Pour Point - the minimum temperature at which oil will flow.
3. Flash Point - temperature at which the oil will ignite by a flame.
4. Fire Point - temperature at which oil will continue to burn after ignition.

Using the previous Text Assignment and Information Sheet answer the following questions.

1. What is meant by viscosity?

2. What is meant by flash point?

3. What three things are needed for combustion?

    (1)

    (2)

    (3)

4. What is meant by pour point?

5. How many grades of fuel oil are there?

6. What is the most popular home heating grade of fuel oil?

MAJOR BLOCK Heating **NAME** ____________

TASK Oil Burning Heating System

UNIT Designing and Installing Oil Piping **TIME (est.)** ______ **(act.)** ______

UNIT NO HE-20

OBJECTIVE(S)

Design and install oil piping and oil tanks for a oil heating system.

START ➔ W-1 W-2 W-3 W-4 C-1

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-20a
W-2 Text Assignment HE-20a
W-3 Information Sheet HE-20b
W-4 Assignment Sheet HE-20a
W-5 ____________
W-6 ____________
W-7 ____________

AUDIOVISUAL(S)

A-1 ____________
A-2 ____________
A-3 ____________
A-4 ____________
A-5 ____________
A-6 ____________
A-7 ____________

LABORATORY ASSIGNMENT(S)

L-1 ____________
L-2 ____________
L-3 ____________
L-4 ____________
L-5 ____________
L-6 ____________
L-7 ____________
L-8 ____________
L-9 ____________

CHECKPOINT(S)

C-1 ____________
C-2 ____________
C-3 ____________
C-4 ____________
C-5 ____________
C-6 ____________
C-7 ____________
C-8 ____________
C-9 ____________

MAJOR BLOCK Heating **NAME** ______

TASK Oil Burning Heating System

UNIT Designing and Installing Oil Piping **TIME (est.)** ______ **(act.)** ______

UNIT NO HE-20

OBJECTIVE(S)

Design and install oil piping and oil tanks for a oil heating system.

START → W-1 W-2 W-3 W-4 C-1

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-20a
W-2 Text Assignment HE-20a
W-3 Information Sheet HE-20b
W-4 Assignment Sheet HE-20a
W-5 ______
W-6 ______
W-7 ______

AUDIOVISUAL(S)

A-1 ______
A-2 ______
A-3 ______
A-4 ______
A-5 ______
A-6 ______
A-7 ______

LABORATORY ASSIGNMENT(S)

L-1 ______
L-2 ______
L-3 ______
L-4 ______
L-5 ______
L-6 ______
L-7 ______
L-8 ______
L-9 ______

CHECKPOINT(S)

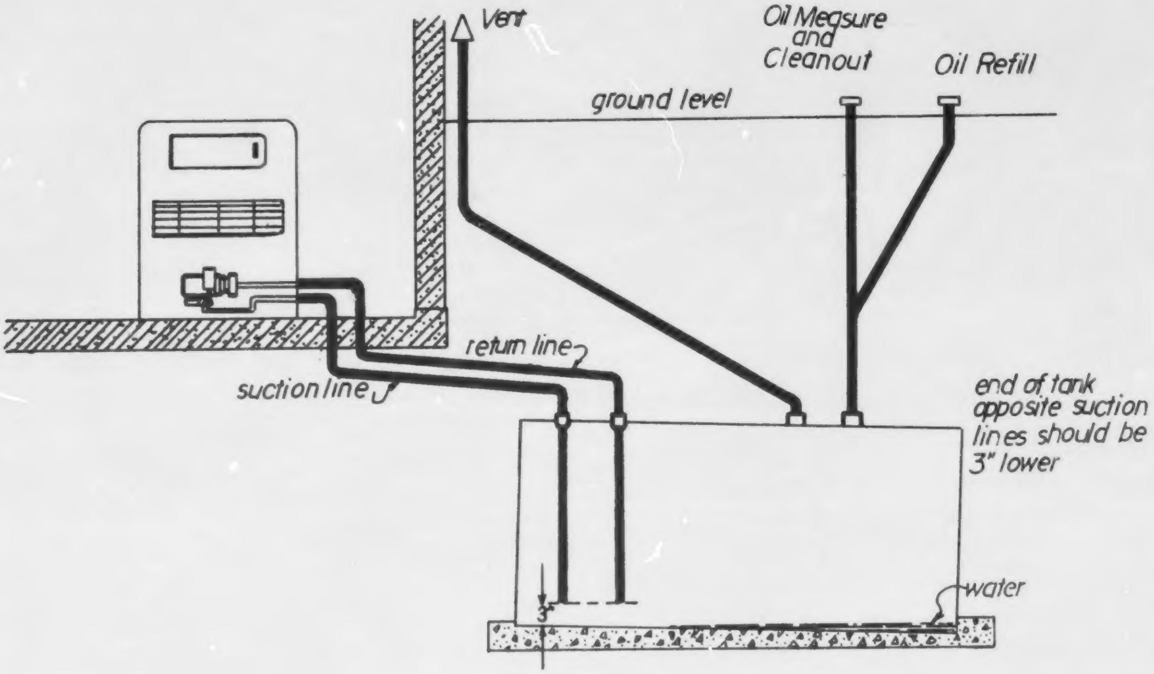
C-1 ______
C-2 ______
C-3 ______
C-4 ______
C-5 ______
C-6 ______
C-7 ______
C-8 ______
C-9 ______

Installing Oil Tanks and Piping

When installing an outside oil tank, the tank should be covered with a rust resistance compound such as tar, asphalt or a rust resistant paint. When preparing the hole for the tank remove all rocks, roots, or any other foreign debris which might damage the seam or chip the tank resulting in increased rusting. Moisture can be considered an important and dangerous problem. Water can cause a chemical reaction which can cause the walls of the tank to corrode and finally deteriorate. In order to prevent this reaction, concrete slabs can be placed on the sides, bottom, and top of the tank. A concrete slab may also serve to anchor the tank to avoid flotation in heavy rains.

Oil storage tanks should be installed with approximately 3 inches (3") pitch. This will allow for condensation and permit water accumulation to move to the lower positions of the oil tank for easy removal. Underground tanks should be installed with suction supply lines extending into the tank to approximately 3" or 4" from the bottom. This will allow adequate room for sediments at the bottom and still leave enough space for the suction valve to function properly. (The suction lines should be located at the higher end of the tank away from water accumulation).

FIGURE A



When installing inside oil tanks, insure that the following rules have been compiled with:

1. A 275 gallon tank does not have to be enclosed by concrete, however, the furnace and oil tank must be separated by no less than five (5') feet when the tank is located inside.

2. A 550 gallon tank must be enclosed in a concrete vault 6 inches thick when it is located inside. If bricks are used instead of concrete walls, it has to be no less than eight inches (8") thick. The tank should be installed on 1¼ inch iron pipe legs to raise the tank off the floor and high enough to provide a natural gravity flow.

3. The suction line for the inside tank should never be placed on the surface of the floor. The soft characteristic of copper tubing will allow it to be easily bent or crimpled causing a restriction of oil flow. A canal or channel should be cut into the surface of the concrete floor to insure that this type of problem does not arise. (Never run oil lines above the burner level. Air has a tendency to collect at the highest point of the lines causing air locks to form).

Accessory Piping

1. A gate value should be placed in the oil supply immediately before reaching the burner.

2. A glove value should be in the line as it leaves the oil storage tank.

3. A vent line is needed to allow the escape of air when the tank is filled and overflow occurs. The vent must be vented to the outside with a cover or lid to avoid the entry of water or moisture into the tank.

4. A 2" oil refill pipe should be located on the tank and extend to the exterior of the building. It should be no closer than two feet (2') from any opening of the building on the same level. (The vent pipe should never be used to fill the tank).

Many communities have local regulations governing the installation of piping in oil burners. These standards should be maintained along with other standards imposed by the National Board of Fire Underwriters.

Operation of One and Two Pipe Systems and Oil Filter Types

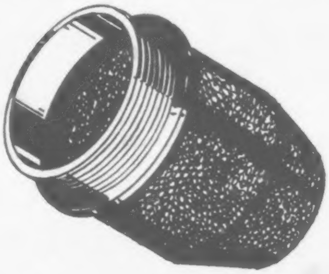
A two-pipe system has two pipes running to the burner or furnace. If the flow of oil is to great, the returning pipe will circulate the oil back to the holding tank. NOTE: The pipe which returns to the tank is called the EXTERNAL BYPASS. If it is returned back through the suction line to the pump it would be an INTERNAL BYPASS. This is the method most often used in modern units.

Oil Filters

There are three types of oil filters, which are as follows:

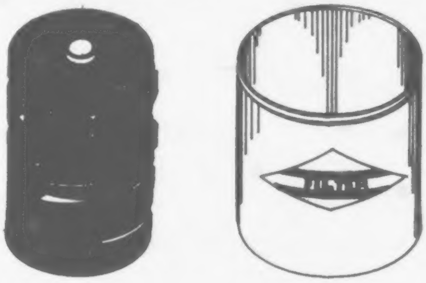
1. The Bronze Bead type - there are thousands of bronze balls linked together. It picks up particles that the screen filters miss.

FIGURE B



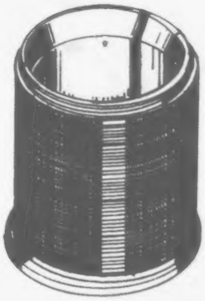
2. Cartridge type - It can be installed at the tank outlet or at the pump. This is so that rust and dirt can not pass through the pump.

FIGURE C



3. Strainer type - wire screen mesh.

FIGURE D



. Draw and label the necessary piping and accessory components to the oil burning systems below.

A. Two-pipe oil burning system (Outside)
Include:
1. Vents
2. Refill
3. Suction line
4. Return line
5. Cleanout
6. Dimension standards

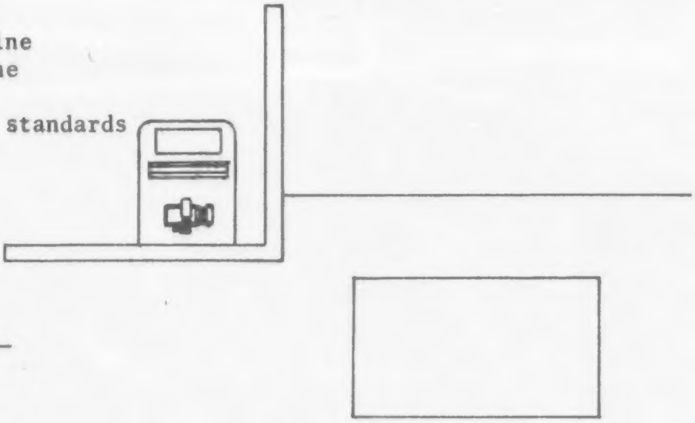
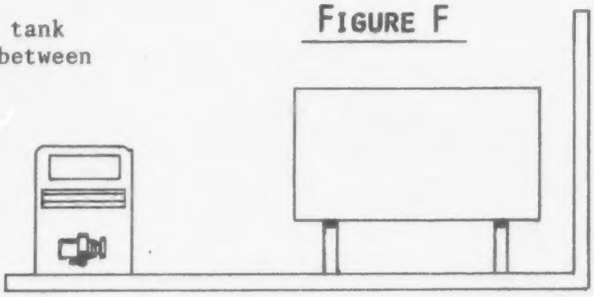


FIGURE E

1. How much pitch should exist for underground tanks?
2. Explain briefly why pitch is necessary for outside tanks?
3. What type of oil burners or fuel pumps should be used for this system?

B. Single-pipe oil burnig system (Inside)
Include:
1. Vents
2. Refill
3. Supply line
4. Oil gage
5. Gate value
6. Glove value
7. Minimum height of tank
8. Minimum distance between tank and burner

FIGURE F



1. Why should the copper tubing supply be placed below the surface of the floor?

2. Why should the oil storage tank be raised above the level of the burner?

3. What type of domestic oil burner fuel should be used with this system?

MAJOR BLOCK Heating **NAME** ______

TASK Oil Burning Heating System

UNIT Installing Oil Burners **TIME (est.)** ______ **(act.)** ______

UNIT NO HE-21

OBJECTIVE(S)

Install a low pressure burner on a domestic oil furnace.

START ➔ W-1 W-2 C-1 A-1 L-1 C-2 L-2 C-3

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-21a	**A-1**	Slide Set HE-21a
W-2	Information Sheet HE-21b	**A-2**	
W-3		**A-3**	
W-4		**A-4**	
W-5		**A-5**	
W-6		**A-6**	
W-7		**A-7**	
LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-21a	**C-1**	Instructor Check
L-2	Job Sheet HE-21b	**C-2**	Instructor Check
L-3		**C-3**	Instructor Check
L-4		**C-4**	
L-5		**C-5**	
L-6		**C-6**	
L-7		**C-7**	
L-8		**C-8**	
L-9		**C-9**	

Introduction to Oil Burners

1. The high pressure oil burners are the most utilized in the field today. Many of its components are used in the operation of burners in other classifications. It is an assembled burner. If mechanic can service one high pressure burner, he can fairly well service them all. Among components is the nozzle, fuel pumps, transformers, ignition assemblies, motor, fan, controls, etc. Grade #2 domestic fuel oil is most popular for the high pressure type burner. Oil is fed to the nozzle under 80 to 100 PSI.

2. The low pressure oil burner uses two streams of air. It has a low pressure oil pump and mixes air and oil inside the nozzle. The air and oil which mixes and leaves the nozzle is called "primary" air while the air moving down the blast tube and meeting the mixture in the combustion chamber is "secondary" air. Operating pressure of these burners use as high as 15 PSI atomizing and operating pressure. It has similar framework and ignition system as the high pressure models, but the fuel pump and nozzle system differ completely.

3. The vaporizing burners can be categorized into two groups: The natural-draft type and the forced-draft type. The natural draft burner is most used where there is no central heating. It is all manual control. The forced draft type is the most popular. Number #1 and Number #2 fuel oil are used in both units. The vaporizing oil burner operates on the principle of a change of state of liquid fuel oil into a gas for the combustion process. Since the burner depends upon heat to prepare the fuel for combustion, it is essential that the pot or retort is heated at all times.

4. Rotary burners consist of two primary types. They are called horizontal and vertical rotary burners. The horizontal burner has a range from below 5 gph to 200 gph. It has the broadest application of any type of burner and utilizes all grades of fuel oil from #2 to #6.

   The burner is called horizontal because it enters the unit on a horizontal plane and prepares the oil for combustion by centrifugal force, spinning it off a cup rotating from 3,450 to 4,900 RPM.

   The vertical rotary burner or wall flame type has a motor speed from 1,450 to 1,550 RPM. The wall-flame vertical rotary is a combination centrifugal action and vaporizing burner.

1. Pump - The pump in the high pressure system draws the fuel oil from the storage tank and delivers it to the burner nozzle at a pressure of 100 PSI. This high pressure is required to force the fuel pump through the small nozzle orifice (hole). The pumps may be single or two stage depending on the application. The two stage pump is used where fuel oil must be lifted more than twelve feet up from the level of the storage tank.

2. Blowers - Operation of the blower draws air down the draft tube and into the turbulator where it mixes with the fuel oil spray from the nozzle. The air inlet is a controlled opening and allows only the amount of air to enter the unit that is necessary for efficient combustion.

3. Electrode Assembly - Ignition of the fuel: Air mixture is accomplished by an electric spark. The assembly consists of two insulated metal rods (Electrodes) placed so as the uninsulated tips are about 1/8 inch apart. When voltage is applied to the insulated ends a spark jumps across the 1/8 inch air gap producing enough heat to ignite the fuel air mixture.

4. Oil Burner Nozzle - The nozzle breaks up or atomizes the fuel oil. This permits oxygen to completely surround the tiny particles of fuel hereby providing a more complete burning. The nozzle is matched to the amount of air entering the unit. If the fuel air ratio is too rich (too much fuel) all of the fuel is not burned resulting in the formation of carbon monoxide. If the fuel air ratio is too lean (too much air) excessive temperatures will be produced causing the fire box to overheat.

5. Transformer - In order to supply the high voltage necessary to jump the air gap of the electrode assembly a step up transformer is used. The transformer consists of a primary and secondary winding. 115 volts at 15 amps is applied to the primary winding. This voltage in induced into the secondary winding resulting in an output of 10,000 watts at 0.023 of 1 amp. The low amperage prevents excessive burning away of the electrode tips while the voltage is enough to jump the air gap.

6. Coupling - The flexible coupling connects the fuel oil pump to the electric motor. Using a flexible connection instead of a rigid one cuts down the noise and vibration that may be transmitted through the burner housing. The coupling is attached to the pump and motor shafts by either set screws or it may be splined.

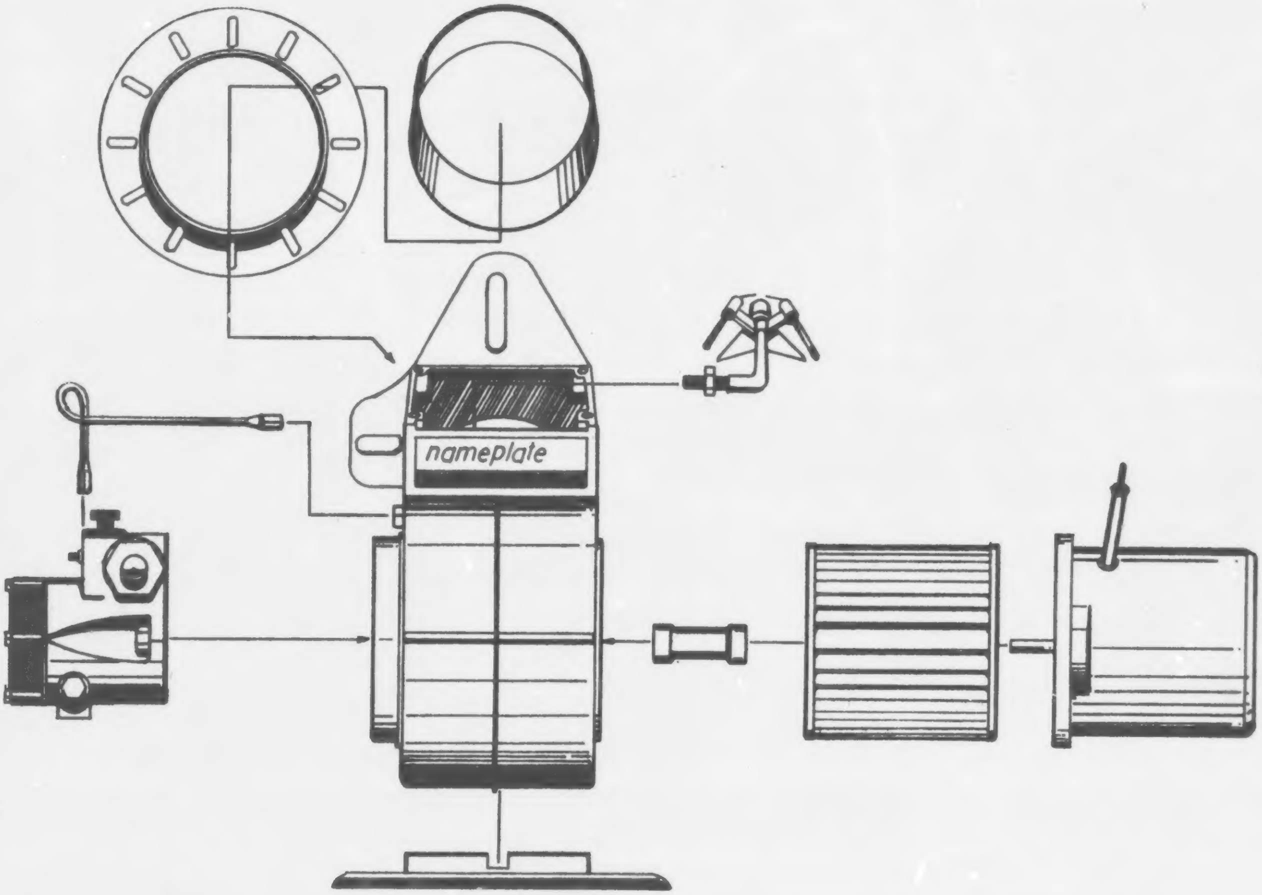
7. Electric Motor - The function of the motor is to operate the blower and oil pump. Most oil burner motors are rated at 115 volts, single phase, 60 cycle and run at 1750 RPM. Burned out windings and faulty bearings are the two major problems of the motor that the service technician will encounter.

The instructor will provide a unit on which a low pressure burner should be installed to manufacturer's specifications and local codes.

Procedure:

1. Consult the appropriate service manual for special installation procedures.
2. Install oil burner assembly to heater housing.
3. Connect oil lines to pump.
4. Make proper wiring connections.
5. Ask the instructor to check all wiring connections. Otherwise equipment may be damaged.
6. Start the unit and determine if it is operating correctly.

The instructor will provide a gun type low pressure burner to disassemble and reassemble. Label each component part as it is disassembled. Use Figure A as a guide.



SIDE VIEW

FIGURE A

MAJOR BLOCK Heating **NAME** ____

TASK Oil Burning Heating System

UNIT Installing and Servicing transformers and electrodes. **TIME (est.)** ____ **(act.)** ____

UNIT NO HE-22

OBJECTIVE(S)

You will learn the correct operation of the ignition system and be able to install and service transformers, and electrodes of an oil burning heating system correctly.

START ➔ W-1 ▷ W-2 ▷ W-3 ▷ W-4 ▷ C-1 ▷ A-1 ▷ L-1 ▷ C-2 ▷ W-5 ▷ C-3 ▷

WRITTEN ASSIGNMENT(S)

W-1 Text Assignment HE-22a
W-2 Information Sheet HE-22a
W-3 Text Assignment HE-22b
W-4 Assignment Sheet HE-22a
W-5 Assignment Sheet HE-22b
W-6 ____
W-7 ____

AUDIOVISUAL(S)

A-1 Slide Set HE-22a
A-2 ____
A-3 ____
A-4 ____
A-5 ____
A-6 ____
A-7 ____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-22a
L-2 ____
L-3 ____
L-4 ____
L-5 ____
L-6 ____
L-7 ____
L-8 ____
L-9 ____

CHECKPOINT(S)

C-1 Instructor Check
C-2 ____
C-3 ____
C-4 ____
C-5 ____
C-6 ____
C-7 ____
C-8 ____
C-9 ____

Weak or defective transformers will cause failure of the unit to ignite the fuel oil. Test each transformer and if there is any doubt as to its condition it should be replaced. When checking transformers use only approved tools and equipment. Remember the job of a transformer is to build or reduce voltage. Commercial transformer testers can be purchased. There is, however, a method of "field" checking transformer units. This method is outlined below.

Do the following before checking the transformer:

1. Remove the motor terminal lead from the relay. This is the number three terminal. It is located in the oil burner junction box . When doing this operation, no oil should be allowed to flow.

2. Remove the access panel of the oil burner so that the hi-tension terminals are exposed to working view. Turn the unit on during the test and off as soon as the test is completed.

The three methods of field testing an Ignition transformer (See Figure A) are as follows:

1. Using a screwdriver with an insulated handle, touch the secondary or hi-tension terminals with one end of the screwdriver while shorting the upper end of the screwdriver against the burner frame or housing. Slowly remove the screwdriver from the frame. Be sure to keep the lower part of the screwdriver against the burner frame or housing. Slowly remove the screwdriver from the frame. Be sure to keep the lower part of the screwdriver on the hi-tension terminals. You should be able to draw the spark out at least 3/4". This would indicate a good transformer, anything less should be replaced immediately.

2. Another method is the neon lamp test. Obtain a neon test lamp. Hold the lamp about ½" to 3/4" away from the high tension terminals. The lamp should burn brightly. If it does not, the transformer should be replaced.

3. The third method will also determine the condition of the transformer. Connect a good set of hi-tension transformer lead wires to the transformer. Hold the end of the leads about ¼" apart. Move them slowly apart up to 3/4 inches. The spark should continue to jump the gap. Anything less, it should be replaced.

After testing the high voltage transformer you should then thoroughly check the entire electrode assembly. (See Figure B).

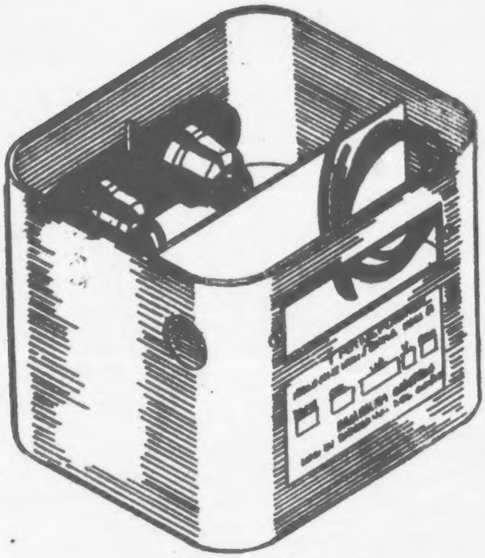


FIGURE A

Start your checking procedure by removing the electrode assembly, then clean and inspect it for cracks. Shut down the oil supply source and begin the testing procedure.

1. Connect the ignition wires to the burner transformer and start the oil burner. Check for any high voltage leaks where the spark seems to jump from the wire or porcelains, other than the electrode tips. If there is a voltage leak, the defective wire or porcelains must be replaced.

2. Turn the electricity "off" on the unit. Remove one high tension ignition wire from the electrode. Be sure the wire is good and has no voltage leaks. Hold the wire in your hand and turn the power on. Holding the wire close to the assembly, move the wire up and down the porcelain, and then up and down the other wire. If a spark gap appears anywhere other than at the metal connectors, the insulator or wire should be replaced. Repeat the test with the other wire.

3. Reconnect the wire as in test one. Turn the unit on. When a spark appears at the electrode tip, blow hard against it while catching for any voltage leaks in the porcelain or wiring. The further the spark is from the tip, the greater the chance of a potential leak occuring.

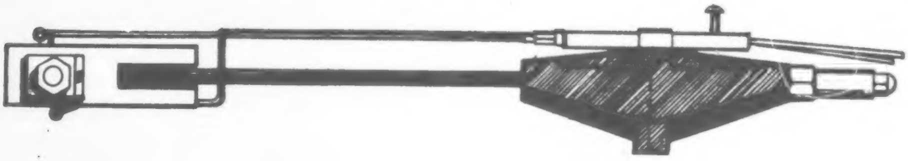


FIGURE B

Assignment Sheet HE-22a

The purpose of the assignment is to familiarize the student with the ignition components of the oil fired furnace.

1. Ask the instructor to assign an oil burning heating unit.
2. Record the make and model number on this activity sheet in the space provided.
3. Examine the unit and locate the tagged parts.
4. Record the number of the tagged part on this sheet in the space provided.
5. Using Information Sheet HE-22a and Text Assignment HE-22b, identify the part and explain its function.

Oil Burning Unit

Make__________

Model__________

TAG NO.	PART NAME	FUNCTION
A. _____	______________	________________
B. _____	______________	________________
C. _____	______________	________________
D. _____	______________	________________
E. _____	______________	________________
F. _____	______________	________________
G. _____	______________	________________

Install and field check the tranformer and electrodes of an ignition system assigned by the instructor.

1. Clean, install, and adjust the electrodes.
2. Install the transformer.
3. Make proper wire connection.
4. Instructor Check
5. Field check the transformer and electrodes.
6. See the instructor and run unit.

Using previous information contained in this unit and the text book, answer the following questions.

1. Name the three basic components of an oil burner ignition system.

   1.

   2.

   3.

2. A transformer is defined as:

3. The voltage needed to produce the spark to light off the oil burner comes from the ____________________ terminals.

4. A spark gap of ____________ inch is an indication of a good transformer.

5. Complete assembly of an electrode consists of:

6. Electrode tips are made of low resistance ____________ steel.

MAJOR BLOCK Heating **NAME**

TASK Oil Burning Heating Systems

UNIT Installing Oil Pumps **TIME (est.)** **(act.)**

UNIT NO HE-23

OBJECTIVE(S)

Install, repair, and service an oil fuel pump unit.

START ➡ W-1 W-2 L-1 W-3 C-1 W-4 W-5

A-1 L-2 W-6 C-2

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-23a
W-2 Text Assignment HE-23a
W-3 Assignment Sheet HE-23a
W-4 Text Assignment HE-23b
W-5 Information Sheet HE-23b
W-6 Assignment Sheet HE-23b
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-23a
L-2 Job Sheet HE-23b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-23a
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3
C-4
C-5
C-6
C-7
C-8
C-9

OIL PUMP OPERATION

The oil or fuel pump, as it is sometimes called, is the means for transfering the fuel oil from the source to the burner, and also raising the pressure of the oil in the lines. Oil pressure must be raised to allow for easier atomization of the fuel oil once it escapes the oil nozzle.

The pump of most oil fired furnaces is connected by means of a flexible coupling to an electric motor on the other side of the housing. The actual rotation of the pump is established through this linkage.

The pump is a major component of the oil heating system and consists of a strainer or filter, a gear pump, and a pressure regulating valve. With these three units in a single housing, it makes a compact unit that is easy to service and adjust, if it is properly understood.

There are several different types of gun oil burners, but all are single or two-stage models. The single-stage unit has one set of internal gears that draws the oil from the tank and delivers it to the spray nozzle under pressure. The determining factor for using a single-stage unit is when lift is not over 12 feet or suction is less than 10 inches. From an economical standpoint, it is less expensive to use.

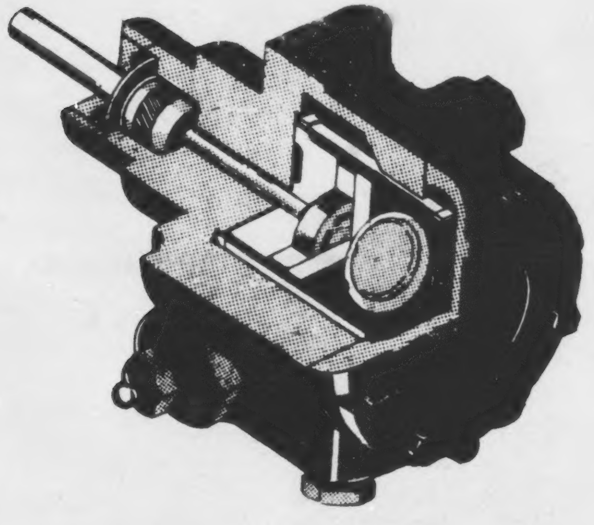
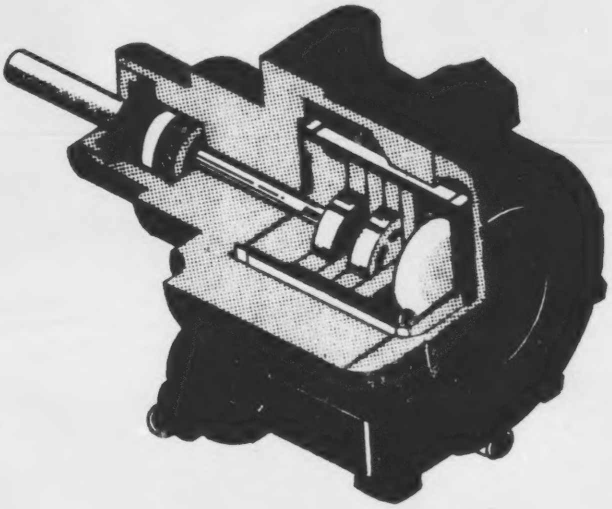


FIGURE A

The two-stage pump is the same as a single-stage except it has two sets of internal gears. One that picks oil up from the storage tanks and delivers it to a storage area within the fuel pump. This storage area is normally the strainer chamber. The other set of gears takes over and moves the oil to the nozzle under pressure. The two-stage unit will always be used when it is not appropriate to use a single-stage unit. A two-pipe system should not be installed without running the return line to the bottom of the tank. This provides an excellent seal against air entering the line and getting to the pump when the fuel is low in the tank.

FIGURE B



The pump's ability to operate constantly for hours and remain cool without lubrication is due to the fact that it has fuel oil passing through it. The actual lubricity of fuel is slight, but a constant change of oil flowing over the gears is enough lubrication for the moving parts of the pump.

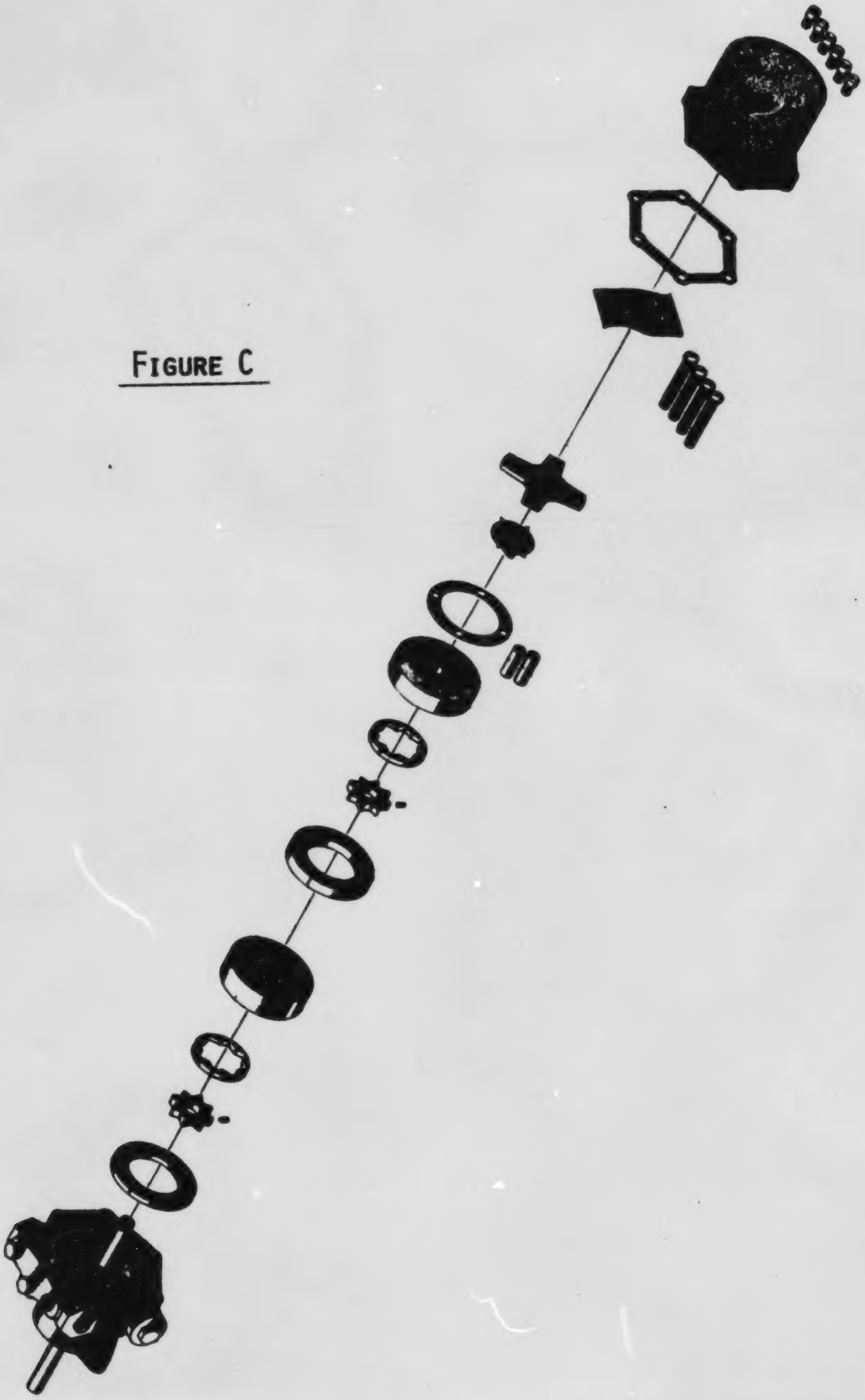
When installing the pump, full consideration should be taken as whether to use a two-pipe system or one-pipe system. The main consideration in determining which to use is the location of the fuel tank. In order to have a proper gravity flow from the oil tank to the fuel pump, the pump's intake port must be lower than the lowest level of the tank. In this situation a one-pipe system is usable. When the burner is above the level of the storage tank, a two-pipe system is necessary. The second pipe in this situation is called the return line and allows the excess oil to return to the tank.

Disassemble and reassemble a two-stage fuel oil pump. Specific manufacturers will provide service manuals appropriate for their products. The instructor will provide a two-stage unit on which to perform this activity.

Procedures:

1. Obtain a service manual for the assigned pump.
2. Remove the pump from the burner and clean the outside area. Play the lines to prevent dirt from entering.
3. Check with your instructor and obtain materials and supplies at this time. (You are responsible for all materials and supplies).
4. Dismantle the pump as shown in the Figure C.
5. When you have completed the work assigned, ask the instructor to evaluate it. Be prepared to answer questions concerning this task.
6. When your work has been completed and evaluated, clean the work area and return all materials and supplies.

FIGURE C



Assignment Sheet HE-23a

1. What is the difference between the single-stage and two-stage oil pump?

2. The fuel pump is a unit and consists of what three parts?

3. What is the purpose of the fuel oil pump?

4. When using the two-pipe system, where should the return line go to? Why?

5. The main consideration as which piping system to use is __________?

6. When lift is not over __________ feet and suction is less than ____ inches, the single-stage unit is used.

7. The oil pump of most oil fired furnaces is connected by means of a ________________ coupling.

SERVICING THE UNIT

The fuel pump is a unit and consists of a strainer or filter, a gear pump, and a pressure regulating valve. These three units in a single housing makes a compact unit that is easy to service and adjust when it is properly understood.

To save time and money always use fuel pump test gauges; never rely on sight, smell, or sound. When called to service a unit, you should:

1. Check for air in the lines.
2. Adjust fuel pump pressure (if needed).
3. Clean fuel pump strainer.
4. Check for internal pump leakage.
5. Check level of storage tank (you may have to change from a one-pipe to a two-pipe system).
6. Check for leaks of any type.

[illegible] bolts, screws, and keys are securely tightened. [illegible] be causes of noises that are very annoying.)

8. Do a vacuum reading with the source of oil to the pump turned off while operating the burner. (This is for drawing power.)
9. Do a vacuum reading while operating the burner with the source of oil turned on. (This is for restrictions in fuel line.)
10. Check fuel pump cutoff.

These are the major items to be checked when servicing a fuel pump. Most of these can be noted by reading your gauges properly.

Job Sheet HE-23b

SERVICE OIL PUMP

The instructor will assign a unit to install a fuel oil pump, adjust and regulate pressure, and to purge and clean the strainer.

Procedures:

A. Familiarize yourself with the unit to be worked on. Review material on oil pumps, if needed.

B. Now begin the servicing procedure.

   1. Check the strainer or filter.
   2. Insure all connections are tight.
   3. Turn fuel on at fuel valve.
   4. Bleed the pump.
   5. Attach high pressure gauge.
   6. Remove adjusting screw cover.
   7. Adjust the pressure (100 pounds per square inch gauge).
   8. Remove pressure gauge.
   9. Attach vacuum gauge.
   10. Check drawing power.
   11. Check for restrictions.
   12. Listen for tank hum or pump noise.

C. When the work has been completed, contact your instructor for an evaluation.

D. Clean the area and return all supplies and equipment to their proper storage compartments.

1. When servicing a fuel pump unit you should always use ________________ ______________________.

2. To raise the pump pressure, you would turn the adjusting screw ________ and ______________________ to lower the pressure.

3. Pump pressure should be set at ____________________ pounds per square inch gauge.

4. What is the purpose of the check valve?

5. When checking fuel pump cutoff, the pressure drops back to zero when the unit is cut off. This would be an indication of _________________, ______________________, or ______________________ cutoff.

6. When doing a vacuum reading with the source of oil to the pump turned off while operating the burner, what would you be checking for with source of oil turned on?

7. You are servicing a single-stage, one-pipe system that is getting the proper amount of fuel to the pump. You also find that the lift from the tank is 18 feet, what should you do?

8. How many flared connections are there on the two-stage pump? What are they?

9. How long do you bleed an oil fuel pump?

10. You should never attemp to regulate the pressure of the oil pump without the use of ___________________?

MAJOR BLOCK HEATING **NAME**

TASK Oil Burning Heating Systems

UNIT Servicing Blower, Nozzle, Motor and Couplings **TIME (est.)** **(act.)**

UNIT NO HE-24

OBJECTIVE(S)

Install and service different types of blowers, nozzles, motors, and couplings on oil burning heating systems.

START ➔ W-1 W-2 W-3 W-4 W-5 W-6 W-7
W-8 C-1 L-1 C-2 L-2 C-3

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-24a
W-2 Text Assignment HE-24a
W-3 Information Sheet HE-24b
W-4 Text Assignment HE-24b
W-5 Information Sheet HE-24c
W-6 Text Assignment HE-24c
W-7 Information Sheet HE-24d
W-8 Assignment Sheet HE-24a

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-24a
L-2 Job Sheet HE-24b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4
C-5
C-6
C-7
C-8
C-9

TYPES OF MOTORS

Many types of electric motors are available from suppliers. It is quite possible that two different types of motors could perform the same job. The service-technician, however, should take caution to select the right motor for a particular job; it will certainly pay in the long run.

Some motors such as the single phase motor, must have some special provision for starting. Others, the three phase motor for example, require no special starting mechanism. Described here are four types of motors designed for easy starting:

1. Split-phase Motor - is used for jobs which do not require a heavy starting load and obtains its full speed quickly. It is used mainly for belt driven or direct drive equipment. The disadvantage of this motor is that it will draw six to eight times its normal current when starting. This could result in a flicker of circuit lights during run up.
2. Capacitor-start Motor - has a high starting and accelerating torque. It is very economical and quiet during operation. When starting, it draws from three to six times its full load running circuit.
3. Shaded-pole Motor - is especially adapted to direct drive equipment and is very economical and dependable where a low starting torque is required. It is one of the simplest types of motors and adaptable to operations where reversibility is not required.
4. Soft-start Motor - was designed originally for agricultural applications. It has a very low starting torque and is used where a large horsepower is required.

There are five types of motors designed for difficult starting loads. They are as follows:

1. Capacitor-start, induction run.
2. Repulsion-start, induction run.
3. Capacitor-start, capacitor run.
4. Repulsion-start, capacitor run.
5. Three-phase, general purpose.

RESET BUTTON:

A motor takes more current to start than it does to run after it gets started. This means that the overload control must allow enough time for the motor to start without opening the circuit.

These are two types of built in protectors: (1) Manual-Reset and (2) Automatic-Reset type. Both types operate on the heat principle (Thermal-overload or Bimetallic strip).

The Manual-Reset means that you must press a button to reset the tripped mechanism before the motor will restart again. The Automatic-Reset will reclose without your aid. When the heater in the control cools, the bimetallic disk will snap into the opposite position closing the circuit allowing the motor to restart.

CHECKING THE MOTOR:

It is important that a solid base be provided for the checkout of any motor that is not secured. Always check the identification plate which usually gives the following information:

1. Required voltage (EMF) supply
2. Hertz (cycle).
3. Running current (amperes).
4. Locked current draw.
5. Temperature rise.

Insure that the voltage is correct prior to connection to prevent possible damage to the motor. When it is operating, the temperature of the hottest part of the motor should not exceed 72°F. above room temperature. This is an average maximum temperature of approximately 150°F. Check the cleanliness and air flow. This could cause the motor to overheat if it is dirty or if the air flow is restricted. Check the current draw of the motor. This can be accomplished by using an ammeter. There are two types of ammeters. One is designed to measure direct current flow and the other to measure alternating current flow.

Most refrigeration air conditioning and heating work requires use of the alternating current ammeter. The current draw of the motor should not exceed the rating listed on the identification plate. If the motor does not start or run properly, check the capacitor. This can be accomplished by using a capacitor tester and analyzer.

IMPORTANT: NEVER PLACE YOUR FINGERS ACROSS THE TERMINALS OF THE CAPACITOR. IT COULD BE CHARGED. ALWAYS SHORT IT WITH AN INSULATED WIRE BEFORE HANDLING IT. IT SHOULD ALWAYS BE PLACED IN A PROTECTIVE CASE PRIOR TO TESTING. THE CAPACITOR COULD EXPLODE IF SHORTED INTERNALLY.

Usually troubles in motors can be classified as:

1. Electrical
2. Mechanical

The electrical trouble may be an open circuit or ground in the field windings. The mechanical trouble could be a defective centrifugal switch.

TYPES OF COUPLINGS

The oil burner drive coupling is used to join together the motor shaft and the pump shaft. It must perform this function securely and quietly. Couplings are available in different lengths and styles and may be purchased in lengths starting at about two inches. They may also be purchased as a kit which comes with an easy-to-carry assortment of lengths, styles, and shaft bushings.

The drive coupling consists of three sections. They are as follows:

1. Blower hub or motor shaft
2. Intermediate or flexible.
3. Pump shaft.

The type of coupling placed between the motor shaft and the pump shaft is completely dependent upon the type of hub on the blower wheel assembly. If a splined hub blower wheel is used on the oil burner, then a splined hub coupling must be used. The four most commonly used couplings are as follows:

1. Flexible hose coupling.
2. Flange coupling.
3. Cushion-flange coupling.
4. Flexible shaft.

The direction of rotation is very important when purchasing a flexible shaft. It must run in the direction for which it is built. This means if the equipment turns in a certain direction, clockwise or counter-clockwise, be sure when placing an order that an indication of the right direction is made.

A drive coupling must perform certain basic functions:

1. It must maintain absolute alignment between the motor and pump shaft.
2. It must prevent transfer or amplification of motor or pump sounds through the burner housing.
3. It must be strong and long lasting.

BLOWERS

The purpose of a blower is to draw fresh air into the burner housing through the control intake opening. When in operation, the blower forces air down the draft tube past the electrode assembly, through the turbulator and into the firebox area. During this process, it provides necessary air for combustion. The blower wheel is measured at its diameter and width, and the two provide knowledge about the ultimate blower output. The blower is mounted on the motor shaft. Blowers are usually of the "squirrel-cage" design and consist of many curved blades assembled in a cylindrical shape and mounted within a housing. Its rotation is determined by holding the unit with the hub facing you. The direction of the blower vanes will then indicate the rotation of the unit. If the blower is of the belt drive type, it should be inspected periodically for slippage and general belt condition. Do not overtighten the belt. A belt should be just tight enough that it does not slip on start. Replace belts that show noticeable cracks or damage. The direct drive blower motor tends to run much warmer than the belt driven motor. The reason for this is the air movement over the motor helps dissipate the heat.

The oil burner blower unit requires very little if any attention. The vanes should be kept clean because excessive accumulation of dirt could reduce its air output. The blower body should not touch the burner housing walls. If it rubs or touches, serious damage to the blower unit could result. When replacing the blower, replace with an identically sized unit, or consult the manufacturer for the correct size unit. Blowers may be equipped with sealed type bearings. These require no lubrication. When they become bad, replace them with new ones. When oiling is required, consult the identification plate on the oil burner blower assembly. Normally it should be oiled every six months of operation (usually at the start of the heating season). Usually SAE 20 weight non detergent oil will be adequate.

NOZZLES

The oil burner nozzle plays a large part in the overall combustion efficiency operation and control of the unit. It permits only a specific amount of fuel oil to be delivered into the combustion area. This is known as gallons-per-hour (GPH) delivery rate. The rate can be changed by replacing one nozzle with another There are three (3) basic oil spray patterns. They are as follows:

1. Hollow cone
2. Semi-hollow cone
3. Solid cone

The oil burner nozzle has three (3) basic functions:

1. it meters fuel.
2. it atomizes the fuel.
3. it provides a uniform spray pattern.

CLEANING

It is very important for the oil burner nozzle to be kept clean. A dirty nozzle may indicate a lack of air where the nozzle is dirty and/or clogged. When cleaning or checking a nozzle, it is best to follow the manufacturer's recommendations. In addition it is a good practice to replace the nozzle rather than clean it. When cleaning is necessary, use clean fuel oil or kerosene and a clean brush. Never use compressed air or oxygen because an explosion may result. It is best to use nitrogen gas, or R12 or R22 Refrigerant gas. Always remember to use eye protection when using any compressed gas when cleaning out plugged nozzles or fuel lines.

Changing

When replacing a nozzle, make sure that the new nozzle has the same specifications as the old one. There are three factors which affect the correct nozzle choice for any installation. They are as follows:

1. type of spray pattern (hollow or solid)
2. angle of spray
3. gallon-per-hour (GPH) firing rate

Sometimes the proper size nozzle is stamped on the nameplate of the unit. The following guidelines may be used for determining the proper flow rate:

1. If the unit rating is given in BTUH INPUT, the nozzle may be determined by:

$$\text{GPH:}\ \frac{\text{BTUH INPUT}}{140{,}000}$$

2. If the unit rating is given in BTUH OUTPUT, the size could be determined by:

$$\text{GPH} + \frac{\text{BTUH OUTPUT}}{(\text{EFFICIENCY\%})} \times 140{,}000$$

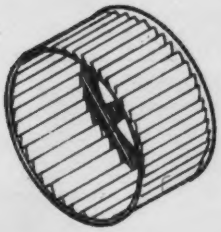
SIZES

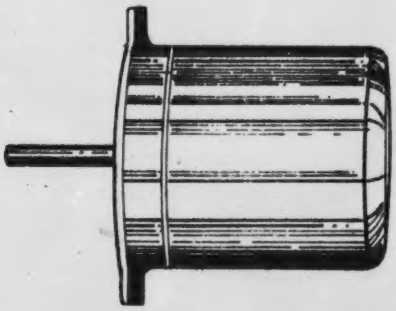
There are approximately 45 different GPH nozzle sizes available, ranging from 1/2 to 100 GPH delivery rate. A one (1) GPH nozzle delivers 140,000 BTU/hr. If the overall efficiency is 60 percent, the useful heat would be 84,000 BTU/hr.

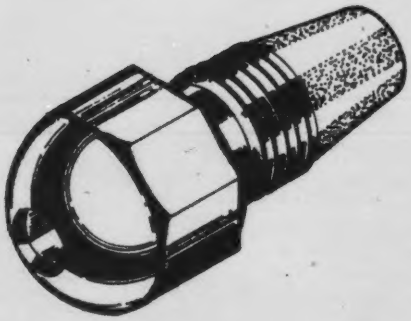
Assignment Sheet HE-24a

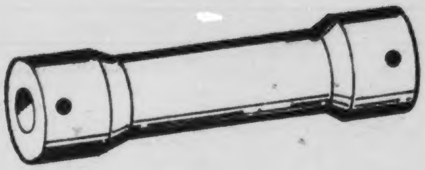
1. Identify the four components listed.
2. Lable the illustrations with their correct names.
3. Locate the four components on three different types of furnaces as provided. (Check with instructor before proceeding with next section).

Unit A	Unit B	Unit C
Furnace Type: ______	Furnace Type: ______	Furnace Type: ______
Serial Number: ______	Serial Number: ______	Serial Number: ______









Remove and Replace a Nozzle

Generally nozzles are not cleaned but are replaced when these conditions exist: smokey flame, flame too small, flame burns to one side, or fire floats and burns on back wall.

PROCEDURE:

1. Check out necessary tools and replacement nozzle.
2. Make sure area and tools are thoroughly clean.
3. Remove the nozzle from the line using the special wrenches.
4. Install new nozzle, keep hands and tools clean when working with the new nozzle.
5. Have instructor check your work.

Remove and Replace the Blower, Coupling, and Motor

The blower is always mounted on the motor shaft. Before removing the blower always check the direction of rotation. When you are facing the hub of the blower the direction of the fins will indicate rotation direction. The coupling shaft will be attached to the motor or blower hub and the pump.

PROCEDURE:

1. Obtain necessary tools and equipment.
2. Make a sketch of the motor wiring and disconnect.
3. Using an Allen wrench loosen the set screw securing the coupling to the pump shaft.
4. Observe the unit and determine if the blower must be loosened from the motor shaft in order to remove motor.
5. Loosen the motor mounting bolts or brackets and pull the motor from housing.
6. Inspect coupling shaft for wear. Look closely at the flexible section for signs of deterioration.
7. Check the blower for dirt accumulation and remove any foreign debris.
8. Check motor as outlined in Information Sheet HE-24a, and visually inspect for overheating, shaft wear, and insulation break down.
9. Re-install components, turn the blower by hand and determine if it is rubbing against the housing.
10. Check with instructor and run-up the oil burner.

MAJOR BLOCK Heating **NAME** ____

TASK Oil Burning Heating System

UNIT Performing the combustion efficiency test **TIME (est.)** ____ **(act.)** ____

UNIT NO HE-25

OBJECTIVE(S)

Be able to recognize types of heat exchangers and vent pipes, and perform the combustion efficiency check.

START ➔ W-1 W-2 W-3 A-1 L-1 C-1

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-25a
W-2 Information Sheet HE-25b
W-3 Information Sheet HE-25c
W-4 ____
W-5 ____
W-6 ____
W-7 ____

AUDIOVISUAL(S)

A-1 Slide Set HE-25a
A-2 ____
A-3 ____
A-4 ____
A-5 ____
A-6 ____
A-7 ____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-25a
L-2 ____
L-3 ____
L-4 ____
L-5 ____
L-6 ____
L-7 ____
L-8 ____
L-9 ____

CHECKPOINT(S)

C-1 Instructor Check
C-2 ____
C-3 ____
C-4 ____
C-5 ____
C-6 ____
C-7 ____
C-8 ____
C-9 ____

TYPES OF HEAT EXCHANGERS

Heat exchangers are of various sizes, shapes, and material but all have one thing in common. They transfer heat from the heat source to a usable form of conditioned air. The heat exchanger in an oil furnace are usually of the drum type and are constructed of cold rolled steel. With the use of the proper blower assembly, the exchanger will raise the temperature of the air passing through it 70-100 degrees F. The heat exchanger will generally have a radiator mounted on the top to provide efficient heat transfer. (See Figure A).

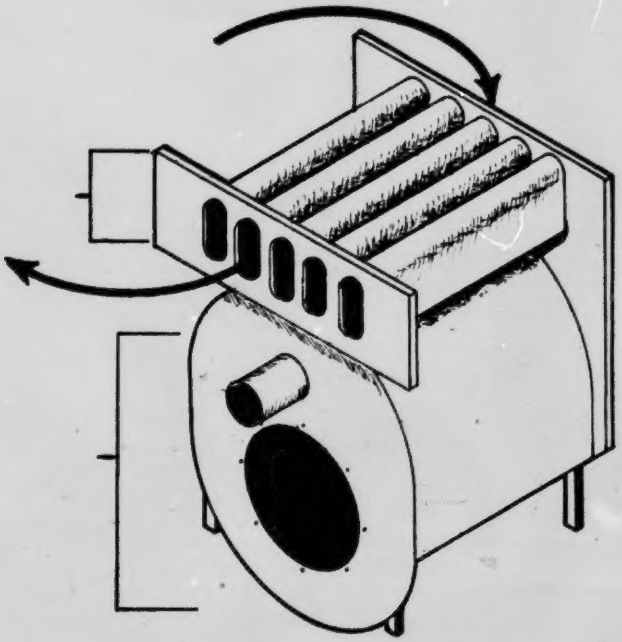
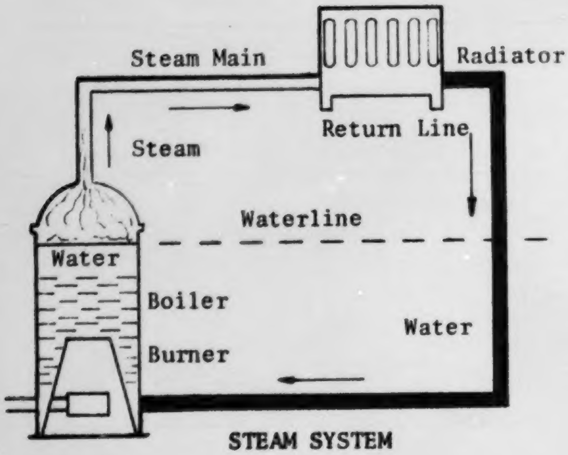
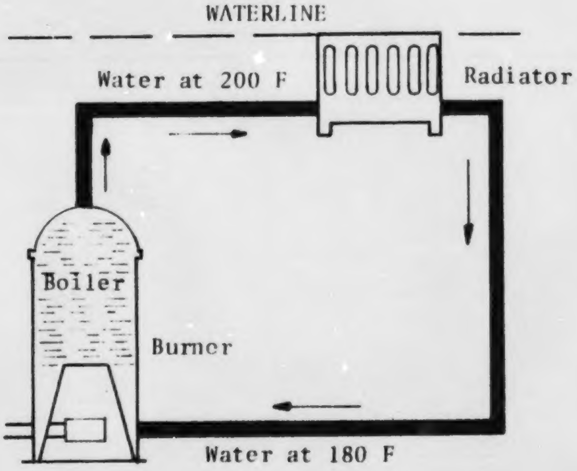


FIGURE A

The lower portion of the heat exchanger is considered the combustion chamber and is treated as a separate part. Some heat exchangers are designed to give up heat to a water medium. (See Figure B). An example would be water which circulates through an oil burner heat exchanger and piped to a remote area. A second heat exchanger such as a radiator would give up its heat into a room some distance away. Still another system would use steam in much the same way as water (See Figure B). The illustrations on the next page show a hot water system, steam system, and a ducted warm air system.


Steam Main
Radiator
Steam
Return Line
Waterline
Water
Boiler
Burner
Water

STEAM SYSTEM


WATERLINE
Water at 200 F
Radiator
Boiler
Burner
Water at 180 F

HOT WATER SYSTEM

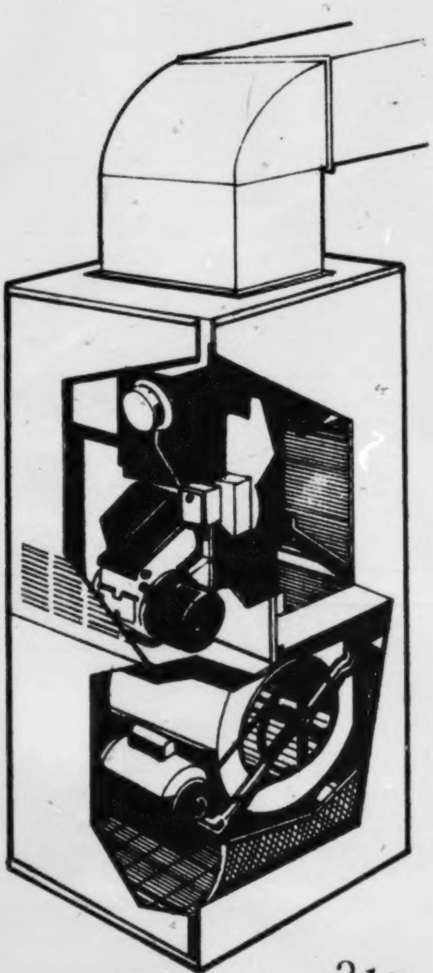


FIGURE B

Venting

The purpose of venting is to remove flue gases to the outside atmosphere and to provide adequate draft for a particular appliance. This is accomplished through the installation of a vent pipe from the appliance to the outside atmosphere or into chimneys of adequate size. An automatic or barometric draft regulator will be used to maintain a constant draft.

The basic types of vent pipe used are single wall and double wall (See Figure C). Single wall is subject to corrosion, leaky joints, weak draft because of heat loss, condensation, moisture drippage, and overheating of nearby combustibles. Single wall has many restrictions placed upon its installation and double wall pipe has only a few restrictions. Single wall must have a minimum clearance from wood of six to nine inches as compared to one inch for double wall. All types of vent piping must be installed in accordance with, national, state and local fire prevention codes.

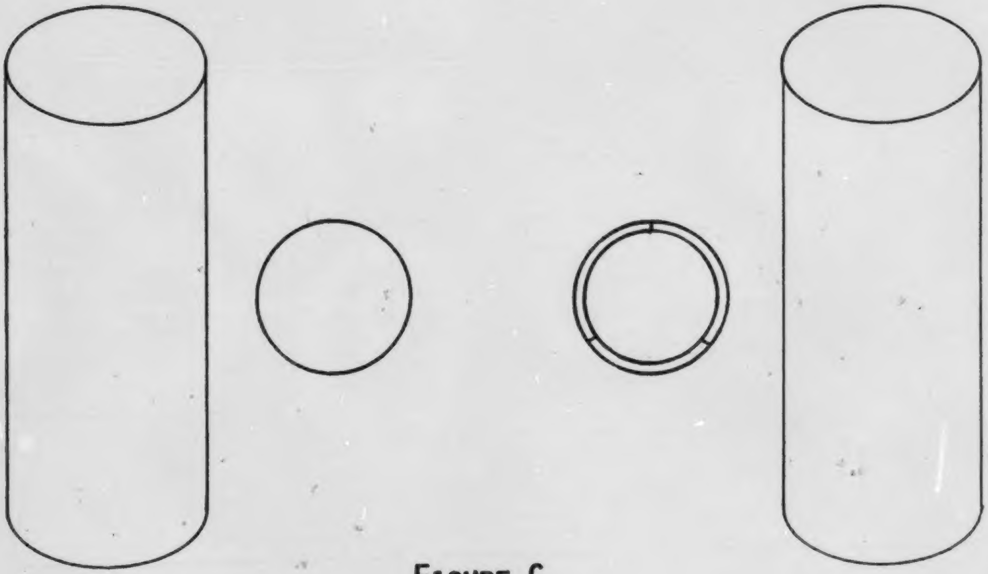


FIGURE C

BAROMETRIC DAMPERS

A correct draft is necessary for good combustion. The creation of adequate draft is the function of the chimney. The draft can be regulated by the use of a barometric draft control. There controls should be located as close as possible to the furnace and are usually installed in the horizontal section of the vent pipe between the chimney and furnace (See Figure D).

The control should be adjusted while the furnace is on and the pipe is hot. The damper has a counter balanced adjustable weight that can be adjusted to maintain proper draft. This adjustment must be done in accordance with the appliance manufacturers installation instructions.

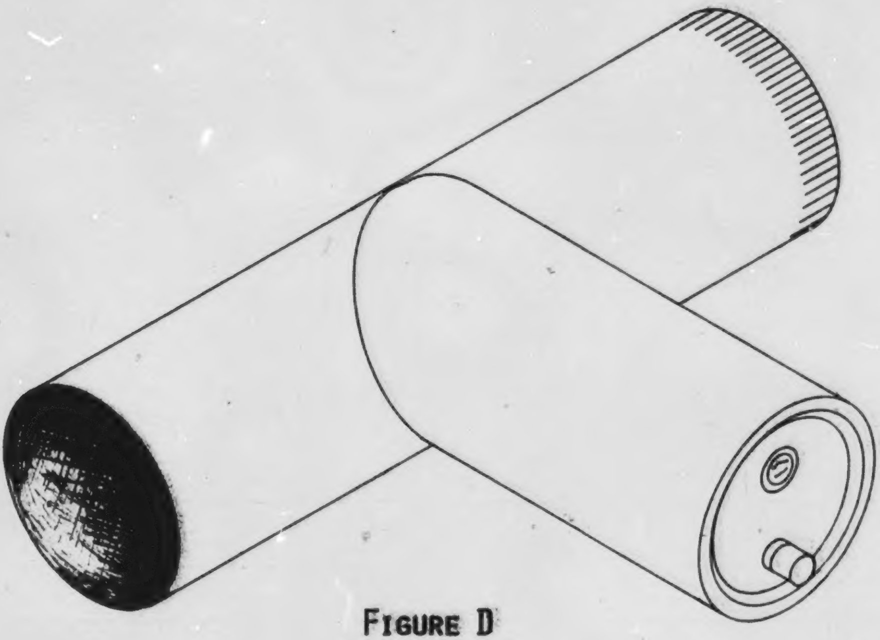


FIGURE D

Job Sheet HE-25a

Using this job sheet as a guide perform the combustion efficiency test. Record all readings on this sheet

A. Perform the CO_2 analysis:

1. Install sampling tube through the hole in the vent pipe and record results here ________.

2. Install longer sampling tube through hole in fire door and record results here ________.

B. Take the stack temperature:

1. Insert thermometer into the vent pipe hole and record
the reading here ___________
Subtract ambient
temperature - __________
True stack
temperature ___________

C. Perform the smoke test:

1. Insert smoke tester into the vent pipe hole and apply readings to scale and record here _______.

D. Perform the draft test:

1. Drill two 1/4" holes (one in the flue pipe and the other in the fire door).

2. Install draft guage sensor in the flue pipe hole and record the results here ___________.

3. Install the guage (with a longer sensor) into the hole in the door and record results here __________.

MAJOR BLOCK Heating **NAME**

TASK Oil Burning Heating System

UNIT Installing Controls **TIME (est.)** **(act.)**

UNIT NO HE-26

OBJECTIVE(S)

Identify and replace primary and safety controls on an oil fired heating system.

START ➔ W-1 W-2 W-3 W-4 L-1 C-1 W-5
W-6 L-2 C-2

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-26a	A-1	
W-2	Text Assignment HE-26a	A-2	
W-3	Information Sheet HE-26b	A-3	
W-4	Text Assignment HE-26b	A-4	
W-5	Information Sheet HE-26c	A-5	
W-6	Text Assignment HE-26c	A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-26a	C-1	Instructor Check
L-2	Job Sheet HE-26b	C-2	Instructor Check
L-3		C-3	
L-4		C-4	
L-5		C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

Introduction to Controls

A control in the oil burning system either operates another control or some specific part of the unit. These controls are designed to run the unit automatically and will open or close a circuit as needed. This protects the system from damage. In the following discussion, these controls will be examined and their functions will be identified.

1. "Turn On" Transformer - The "Turn On" transformer is a low voltage (24V) transformer. It normally provides 24 volts for the furnace control circuit. It may be used to control the heating circuit or the air conditioning controls. Always check the wiring diagrams which will indicate the type of transformer supplied with the furnace.

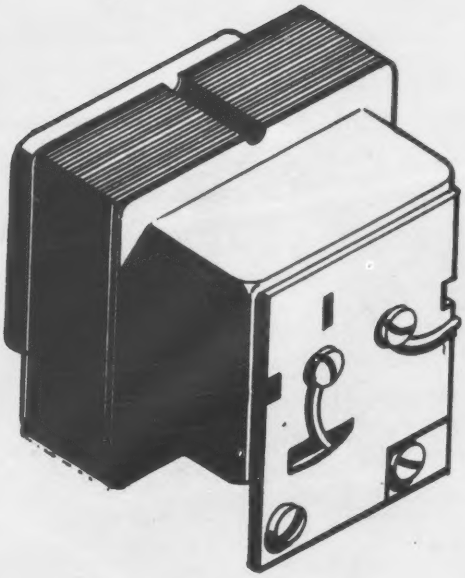


FIGURE A

Turn-On Transformer

2. Turn On Pump and Blower - When the thermostat calls for heat, it activates the pump. This supplies oil under pressure through various size nozzles. The turn on blower provides a constant air flow for combustion to sustain burning in the furnace. This centrifugal blower is driven by the burner motor. Proper rotation of the motor is important. An arrow will usually indicate the direction of rotation.

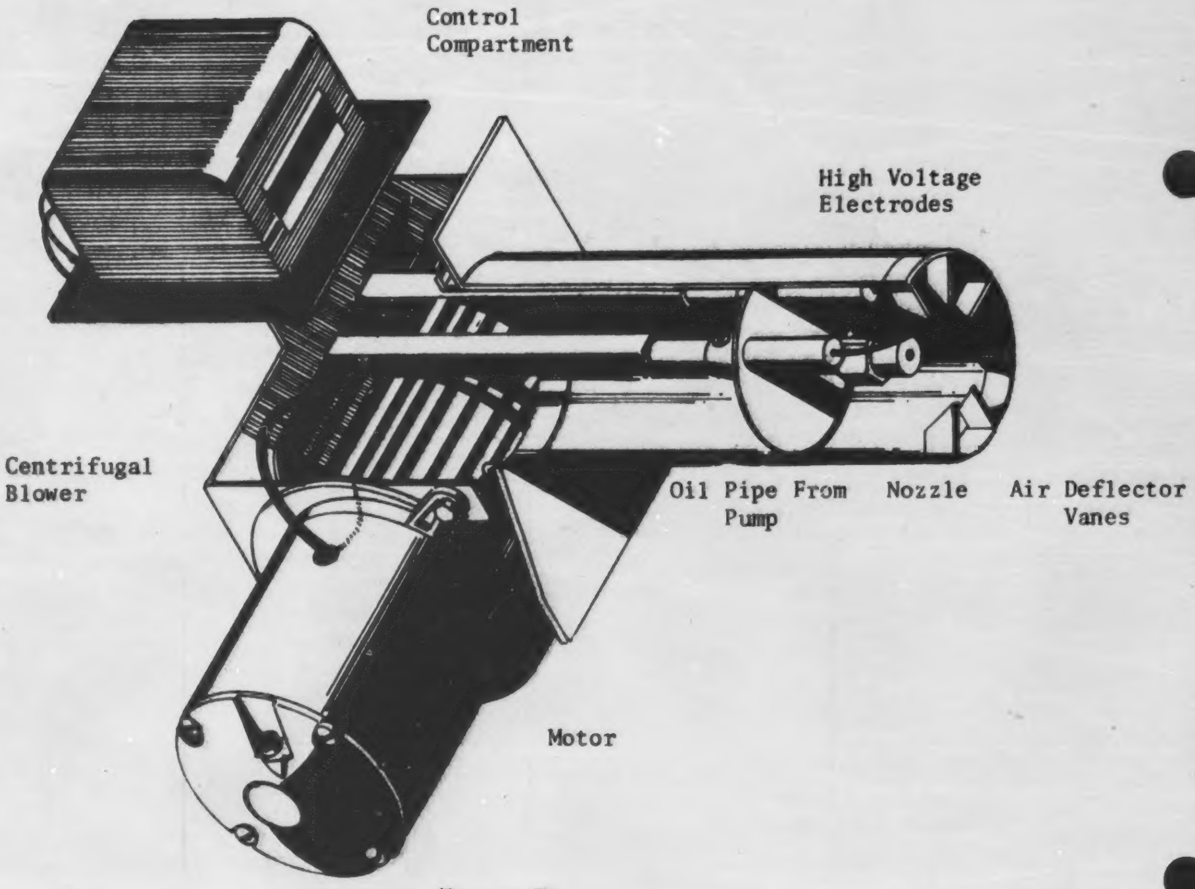

Control
Compartment
High Voltage
Electrodes
Centrifugal
Blower
Oil Pipe From
Pump
Nozzle
Air Deflector
Vanes
Motor

FIGURE B

3. Constant Ignition Switch - The thermostat calls for heating the switch is turned on. This switch allows the ignition transformer to provide a constant spark across the igniters through out the heating cycle. The constant ignition stack switch is located on the unit's front partition on the left of the burner. It is electrically connected to the stack switch by a low voltage cable, however, the constant ignition if mechanically separated from the stack switch.

4. Intermittent Ignition Switch - This switch is basically the same as the constant ignition switch except that sparks are provided only for a short time. When the thermostat calls for heat, the transformer provides a spark for 30 - 40 seconds. When igniton occurs it drops the transformer out of the circuit. This switch is connected to the stack switch in the same manner as the constant ignition switch. The intermittent ignition switch will be found in units that were manufactured before 1974. Whereas, the constant ignition switch will be found in newer models after 1974. On either unit, failure to establish flame for any reason would cause the safety switch to open and cause the unit to shut down.

PRIMARY CONTROL

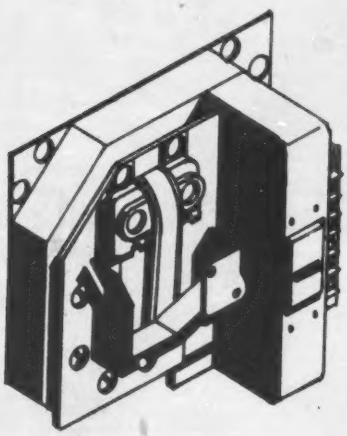


FIGURE C

5. Stack Switch - Relatively speaking, the stack switch controls both the constant ignition and the intermittent switch. It is the most common cause of complaints by homeowners with oil heat. This is because it does its job so well. It is a safety control switch and is designed to close the system out if the proper flame is not established and maintained. The stack switch is electrically connected to the safety heater in the primary control and is located in the stack elbow.

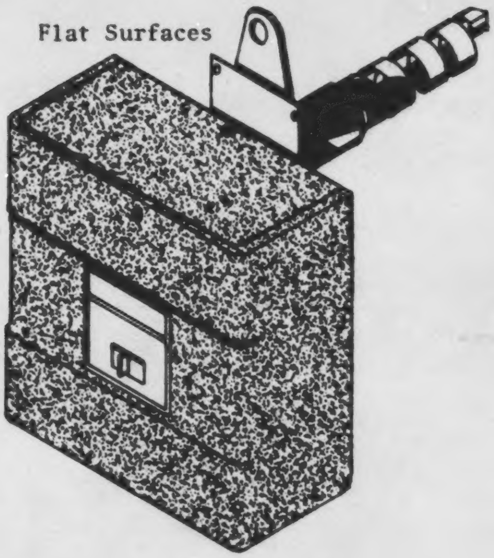


FIGURE D

Fan and Limit Control

Fan and limit control switches serve as part of the safety precautions which are incorporated into the system.

Fan Control - The fan control along with a sensing element is positioned into the air stream inside the furnace. Contacts which are normally open respond to temperature changes inside the furnace. When the burner is on, the termperature increases. This causes the contacts to close which completes the electrical circuit to the blower motor and starts the blower. It will continue to run as long as the contacts in the fan switch remain closed. When the desired thermostat temperature is reached, the burner stops. The blower, however, continues to operate until the temperature decreases. The contacts of the fan control will open and stop the blower when air temperature is lowered to the range setting on the thermostat.

Limit Control - The limit control has a sensing element that responds to temperature change. It also serves as a safety device which stops the burner operation when too much heat is generated in the unit. The limit control is unique in the fact that it will not function when the unit is operating under normal conditions. Its contacts are normally closed and it is positioned in the line voltage circuit which leads to the transformer. When the temperature in the unit reaches the thermostat setting (set by manufacturer), the contacts will open automatically and interrupt voltage to the transformer which will stop the burner. When temperature is lowered, contacts will close. Proper voltage would then be restored for normal operation.

Location of Components on Unit

The instructor will assign a unit on which at least four (4) primary controls must be identified and labeled.

After becoming familiar with the unit the following controls should be identified and labeled:

a. Turn on pump and blower
b. Turn on transformer
c. Fan and limit control
d. Cadmium Cell (CAD Cell)
e. Ignition stack switch

Ask the instructor to check the components and component names to determine if components have been appropriately identified.

Wiring of Components into Unit

The basic purpose of controls in the oil burning system is for safety and primary control functions. Primary controls are designed to either stop or start the unit. Safety controls stop, start, and/or operate the unit. All oil fired furnaces should have one or more safety controls and some type of primary control. Some older models currently in operation may not be provided with devices utilized for safety control.

It is important at this point to determine the appropriate procedures for wiring the controls correctly. It is important to remember that various manfacturers produce oil fired units and each has wiring instructions. The basic designs however, are generally the same. To insure that components of the oil fired unit have been wired correctly the manufacturer's service instructions and specifications should be followed.

Since the basic design of different units are the same, the following diagram may be applied to different manufacturer's equipment. It is important to note, however, that the position or location of components may differ to some extent. Review the diagram for general operation of oil fired units, but refer to specific service manuals before wiring controls on laboratory equipment.

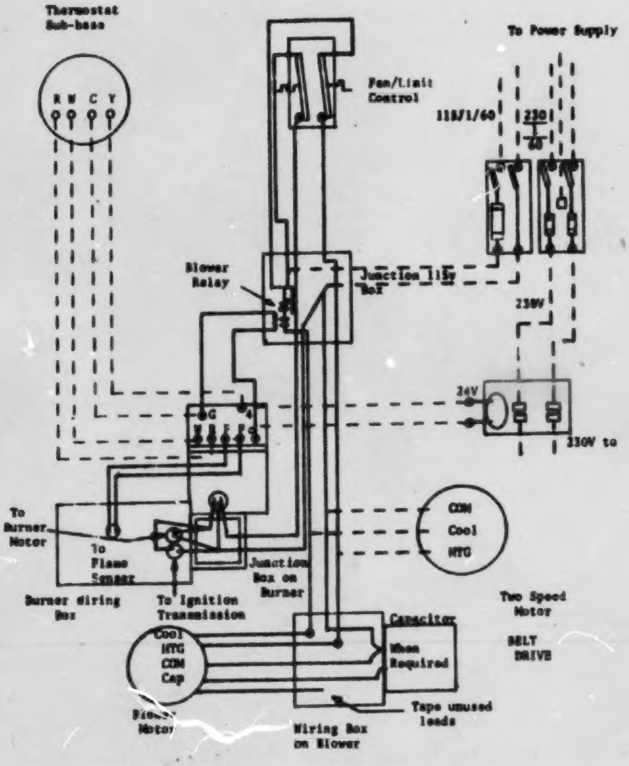

Thermostat Sub-base
R W C Y
Fan/Limit Control
To Power Supply
115/1/60
230 60
Blower Relay
Junction Box
115V
230V
24V
230V to
G 4
To Burner Motor
To Flame Sensor
Burner Wiring Box
To Ignition Transmission
Junction Box on Burner
COM
Cool
HTG
Two Speed Motor
BELT DRIVE
Capacitor When Required
Cool
HTG
COM
Cap
Blower Motor
Wiring Box on Blower
Tape unused leads
DIRECT DRIVE

FIGURE E

Wiring of Unit

The instructor will assign the unit on which this job will be performed. Use the following procedures to wire the controls of an oil fired unit. These components should be wired into the unit. Consult the instructor before operating the unit after each installation.

A. Fan limiter control
B. Low voltage transformer (24 V)
C. CAD Cell
D. Constant ignition control (Intermittent ignition control in older units)
E. Turn on pump and blower
F. Stack switch

MAJOR BLOCK Heating **NAME**

TASK Oil Burning Heating Systems

UNIT Performing pre-season start up and check **TIME (est.)** **(act)**

UNIT NO HE-27

OBJECTIVE(S)

You will learn how to perform pre-season start up and check.

START → W-1 A-1 L-1 C-1

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-27a	**A-1**	Slide Set HE-27a
W-2		**A-2**	
W-3		**A-3**	
W-4		**A-4**	
W-5		**A-5**	
W-6		**A-6**	
W-7		**A-7**	
LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-27a	**C-1**	Instructor Check
L-2		**C-2**	
L-3		**C-3**	
L-4		**C-4**	
L-5		**C-5**	
L-6		**C-6**	
L-7		**C-7**	
L-8		**C-8**	
L-9		**C-9**	

Performing Pre-Season Start Up and Check Out

Nozzle - Small particles of dust, dirt, rust or lint, can work their way into the nozzle. It must be checked at the beginning of every heating season. When the nozzle has been removed from the adapter, clean tools should be used for the assembly. Remove the nozzle strainer with a screwdriver. If it is dirty, wash or soak it in a good solvent. After cleaning, inspect the nozzle, and if damaged, replace with a new one.

Operation of Primary Controls - Most safety controls are set at the factory and require no adjustment. Observe the general condition of the wiring. Make sure the wires are making good connection. The following procedure may be used to check out Honeywell controls. Consult the manufacturer service manual on different types of appliances. For flame detector, check the following:

1. Open the line switch, wait 3 minutes, and operate the red manual reset lever.
2. Remove the lead wires from the SS terminals on the primary controller (see SS Terminals Information Sheet).
3. Push one leadwire of the 1,500 ohm resistor into one of the SS Terminals and close the switch. The burner would start as soon as the flames have been re-established. Push the second resistor lead into place on the other SS terminal. NOTE that this must be done before the safety switch can lock out (approximately 70 sec., 60 sec., Model 81826 E.F.)
4. If the primary controller locks out with the resistor across the SS Terminals, the primary controller should be replaced.

Fan - the fan will be direct drive or belt drive. Check its operation by going to the thermostat, fan setting to the on position. This will allow operation of the fan motor only. If the fan fails to start check the wiring to the motor. If there is power from the thermostat to the motor, and the fan will not operate. This will mean that the motor needs repairing or replacing.

The Limit Control Switches - The limit control is simply a high limit protection against over heating of the furnace due to dirty filters or other causes which do not allow proper air circulation. These are factory adjusted and do not change.

Combustion Efficiency - There are four instruments used in combustion testing: the draft guage, the CO2 indicator, the stack thermometer, and the smoke tester.

1. The draft guage - An over fire draft reading of not less than .02 inches of water may be considered sufficient to develop and maintain proper combustion.

2. The CO2 indicator - Where the net flue gas temperatues are less than 400°F, a CO2 reading as low as 8% may be considered satisfactory. Where the net flue gases are over 500°F, CO2 reading at least 9% to 10% should be the target.

3. The stack thermometer - For a final determination of the true stack temperature, subtract the basement air temperature from the stack reading. Example: stack reading 700°F, basement temperature 60°F. 700°F - 60°F = 640°F.

4. The smoke tester - The objective of this test is to measure the smoke content of an oil heating installation, and its relationship with other combustion test results. It is used to set the burner operation according to readings on an indicated smoke scale that accompanies the smoke test instrument.

Fuel Pump Pressure - All fuel pressure adjustments on an oil unit should be made by guage readings. Put the burner in operation and adjust the pressure. Normally, it is set at 100 p.s.i. or at the pressure setting specified by the manufacturer.

Ignition System - One method of field testing a transformer unit is to use an insulated handled screwdriver. Touch the hi-tension terminal with one end of the driver while shorting out the upper end of the tool against the burner frame or housing. Slowly draw the upper part of the tool away from the frame, continuing to hold the point of the screwdriver on the hi-tension terminal. Note the length of the spark which can be drawn out during this operation. A strong unfaltering spark of a least 3/4 inch is indicative of a good transformer - anything less than this is subject to immediate replacement.

Fuel Oil Filter - For proper installation the filter should be as close to the inlet side of the pump as possible. The cartridge traps dirt, rust, and scale and should be replaced when making the pre-season start up and check.

Job Sheet HE-27a

Using this checklist perform a pre-season start up. Check with the instructor before starting the unit.

Item to be checked	Steps taken to clean, service or repair
1. Nozzle	1.
2. Primary controls	2.
3. Fan unit	3.
4. Limit control switches	4.
5. Combustion efficiency	5.
6. Fuel pump pressure	6.
7. Ignition system	7.
8. Fuel oil filter	8.

MAJOR BLOCK Heating **NAME** ____________

TASK Oil Burning Heating Systems

UNIT Troubleshooting the Oil Burning Heat System. **TIME (est.)** ________ **(act.)** ________

UNIT NO. HE-28

OBJECTIVE(S)

Troubleshoot and repair the fuel-oil burning heat system.

START → A-1 → W-1 → L-1 → C-1 → L-2 → C-2 → L-3 → C-3 → L-4 → C-4 → L-5 → C-5 → L-6 → C-6 → L-7 → C-7 → L-8 → C-8

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet HE-28a	A-1	Slide Set HE-28a
W-2		A-2	
W-3		A-3	
W-4		A-4	
W-5		A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet HE-28a	C-1	Instructor Check
L-2	Job Sheet HE-28b	C-2	Instructor Check
L-3	Job Sheet HE-28c	C-3	Instructor Check
L-4	Job Sheet HE-28d	C-4	Instructor Check
L-5	Job Sheet HE-28e	C-5	Instructor Check
L-6	Job Sheet HE-28f	C-6	Instructor Check
L-7	Job Sheet HE-28g	C-7	Instructor Check
L-8	Job Sheet HE-28h	C-8	Instructor Check
L-9		C-9	

Troubleshooting Procedures

One important method whenever troubleshooting a unit is to have a step-by-step procedure to follow. This can save time and facilitate the solution to the problem. Always use good common sense and think out the problem. (What are the symptoms?) Most oil burner complaints can be divided into three (3) main types.

1. The "No Heat" call.
2. Insufficient or too much heat call.
3. The "Defective Operation" call (smoke, odor, noise, etc.)

The following is an example of a step-by-step procedure:

The "No Heat" call

1. Check the main fuse and power supply.
2. Check the fuel-oil burner fuse.
3. Check fuel-oil burner remote control switch.
4. Check fuel-oil tank level.
5. Inspect the combustion area for evidence of fuel-oil.
6. Check the limiting control switches for open circuit.
7. Check for burner motor operation.
8. Test the thermostat for proper operation.

Another good point to remember when troubleshooting a unit is to start with the easy to check items first and then work your way to the more difficult ones. This will usually save valuable time.

The primary control is the heart of the oil burner control system. It operates under control of the thermostat and limit controls to supervise the burner operation. Each of those controls responds to a go or no-go signal. In a properly designed and installed system, the controls provide safe burner operation to satisfy a need, or they shut down the burner when the need is satisfied or when an unsafe condition exists. Whenever troubleshooting the oil burner system, one should begin at the primary control. It is the center of the control system and each of the circuits of the oil burner system can be checked. The type and location of the primary control depends on what type of flame detector is installed. There are two types. (1) visual (2) thermal. The visual (cad cell) is used with controls that are designed for oil burners, hot water heaters, and for hydronic heating systems. They are the mounted type and always separate from the primary control. The thermal (stack type) flame detectors may be included or separate from the primary control. It is usually mounted in the stack where the detector is in the direct path of hot stack gases. Both flame detector primaries are available with either constant or intermittent ignition. As stated in a prior section, the constant ignition comes on when the burner motor is energized and stays on as long as the oil burner is firing. The intermittent ignition comes on when the burner motor is energized and goes off either when the burner flame is established or after a preset ignition timing period. The primary control uses the information transmitted to it from the flame detectors to shut down the oil burner or allow it to operate through the use of a safety switch. The safety switch consists of a small bimetal element and a separate safety switch heater.

When there is no flame, current is allowed to pass through the safety switch heater by the flame detector, and the bimetal heats and starts to warp. When it warps sufficiently, the safety switch breaks and the system shuts down. The safety switch must be manually reset any time it opens. If flame is established, the flame detector acts to bypass the safety switch heater and allow the burner to operate. To check the cad cell and primary control system, perform the following checks:

1. Remove the cad cell leads at the primary control. The burner should stop. If it does not, the primary control is faulty and should be replaced.

   Did the burner stop: Yes ____ No ____
   (Check one)

2. After two minutes, connect an ohmmeter to the cad cell leads and read the resistance. It must be more than 100,000 ohms. A lower reading indicates light leakage into the burner. Check all opens and seals.

   Record Reading here: ________________

3. Push the reset on the primary control. The burner should start. Jump the cad cell connections. Read the resistance of the cad cell. It should not be more than 1500 ohms. If the resistance exceeds 1500 ohms, the cad cell requires cleaning or replacing. Also, if the control locks out with the terminals jumped, then it must be replaced.

   Record Reading here: ________________

TROUBLESHOOTING GUIDE FOR THE PRIMARY CONTROL

Needs Repair or service	OK		
☐	☐	1.	Check to see if thermostat is calling for heat.
☐	☐	2.	Check if line switch is closed.
☐	☐	3.	All connections are tight.
☐	☐	4.	Limit switch is closed.
☐	☐	5.	Burner switch closed.
☐	☐	6.	Check for no tripped overloads.
☐	☐	7.	Reset safety switch.
☐	☐	8.	Check pyrostat or cad cell detector.
☐	☐	9.	Check for voltage at primary control.
☐	☐	10.	Check for proper flame and ignition.
☐	☐	11.	Check for fuel-oil in combustion chamber.
☐	☐	12.	Check for defective motor.

The fuel supply tank usually has a two-pipe system. One line carries fuel-oil from the tank to the burner and is called the suction line. The other line returns the excess fuel-oil to the tank and is called the return line. This type of system is used when the fuel-oil storage tank is lower than the burner. When the fuel-oil storage tank is higher than the burner, then a one-pipe gravity-fed system is used. This means that the fuel-oil feeds by gravity to the fuel-oil burner. Proper venting and filler piping are important to uninterrupted fuel-oil flow. A shut-off valve and fuel-oil filter should be located at the bottom (outlet) of the fuel-oil storage tank. The vent pipe should be at least one (1) inch in diameter and the fill pipe a minimum of two (2) inches in diameter. Always refer to manufacturer's fuel pump spec. sheets for proper line sizes. Remember that a fuel-oil storage tank should be at least 7 feet from the furnace, and always installed in accordance with underwriters and local regulation.

A fuel oil filter is a must and is installed between the fuel-oil supply and fuel-oil pump. This filter stops dirt and foreign matter from entering the fuel-oil pump and nozzle area. There are various types of fuel-oil filters in use with the most popular being the spin-off/on type. The fuel-oil filter should be changed regularly. Whenever troubleshooting fuel-oil flow problems, see what set-up exists, and check for proper installation, size, etc.

The instructor will assign a shop furnace to inspect for a "No heat call". Use the following check list as the first step in troubleshooting.

Needs Repair or service	OK	
☐	☐	1. Fuel-oil tank empty.
☐	☐	2. Ventline opening closed.
☐	☐	3. Fill line cover off. (missing)
☐	☐	4. Defective shut-off valve.
☐	☐	5. Clogged or leaking fuel-oil filter.
☐	☐	6. Connections for air leakage.

Job Sheet HE-28c

Oil Pump

The oil-burner fuel-pump consists of a strainer or filter, a gear pump, and a pressure regulating valve. Its combination in a single housing makes a compact unit that is easy to adjust and service. Most difficulties in pump servicing depend upon the proper diagnosis of the cause of trouble by recognizing certain symptoms, the serviceman can quickly locate and solve the problem.

Use this check list to inspect the fuel oil pump on the assigned furnace when there is an indication of lack of fuel.

Needs Repair or service	OK	
☐	☐	1. Check for loose couplings.
☐	☐	2. Pressure set too low or too high.
☐	☐	3. Check for a defective pressure regulating valve.
☐	☐	4. A sticky by-pass valve.
☐	☐	5. Dirty oil pump strainer or filter.
☐	☐	6. Check for air leaks in suction line.
☐	☐	7. Pump gears worn.
☐	☐	8. A defective oil pump seal.
☐	☐	9. Water or dirt in the fuel oil.
☐	☐	10. Restricted or clogged fuel lines.
☐	☐	11. Pump partially air bound.
☐	☐	12. Check motor to see if it comes up to speed.

Job Sheet HE-28d

NOZZLE

The fuel-oil burner nozzle is one of the most precisely made parts of the ordinary burner unit. The orifices at the center of the nozzle can be as small as ten thousands of an inch (0.010) and the slots in the distributor insert as small as five thousandths of an inch (0.005). The nozzle should be handled with some care and understanding, if it is to perform the job for which it was designed. They should never be carried around loosely in the pocket or in a container unless they are covered. The purpose of this protection is to prevent dirt from entering the nozzle, because small particles of dust, dirt, rust or lint can work their way into a nozzle and cause additional problems. Always inspect the nozzle for cleanliness even though it is new prior to installation. Remember, the major cause of nozzle trouble is dirt.

Some manufacturers recommend changing the nozzle each year because the tips are subject to considerable erosion by the oil. Whenever selecting a new nozzle, always follow the manufacturer's recommendations. Be sure to get the right type, spray angle, etc. for the unit.

Check the following points for fuel spray problems on the furnace assigned. The following is a troubleshooting guideline:

Needs Repair or Servicing	O.K.	
☐	☐	1. Inspect for a loose nozzle.
☐	☐	2. Check for correct size nozzle.
☐	☐	3. Check to see if nozzle is centered and at a proper height.
☐	☐	4. Inspect for a dirty nozzle.
☐	☐	5. Check for incorrect fuel-oil pump pressure.
☐	☐	6. Check the nozzle for proper angle spray.
☐	☐	7. Inspect fuel-oil for water.
☐	☐	8. Inspect for excessive carbon build-up in the combustion chamber.

Job Sheet HE-28e

TRANSFORMER AND ELECTRODES

The purpose of the ignition system is to provide enough spark to ignite the fuel oil that enters the combustion chamber. This is accomplished by an ignition transformer, high voltage ignition cable/bus bar, and electrode assembly. These components are among the easiest to recognize and solve whenever troubleshooting the fuel oil burner. In most cases, the service consist of making the proper spark gap adjustment, cleaning electrodes, and securing all connections. The ignition cable or bus bar is used to transport the high voltage that is produced by the ignition transformer to the electrodes. The cable is usually multistrand copper wire with heavy insulation and the metal electrode rods are made of nickel-chromium alloy. The electrodes provide the spark for light-off within the combustion chamber. They are rounded at the tips to provide a greater surface of dispersal for the spark and to prevent arcing or burning away of the metal. The electrodes are held by ceramic insulators which prevent shorting of the metal rod. Whenever the insulators become cracked, the electrodes must be replaced with new ones. Also, the ceramic insulators will become impregnated with dry carbon or oil film of soot. This can usually be removed by wiping them clean with a cloth dipped in a good solvent. If the carbon or soot can not be removed, then replace the electrode assembly. The insulators also serves as a holder so the electrode rod and tip can be aligned and properly adjusted. The spacing of the electrodes depends upon the size of oil burner you are working on. Always consult your manufacturer's spec sheet for the proper spacing. The electrode tips can be cleaned by using a file to obtain a flattened cone point.

If there is plenty of fuel use the following checklist to determine if their is proper spark for ignition. The instructor will assign a furnace for this job.

Needs Repair or Servicing	O.K.	
☐	☐	1. Check condition of high voltage cable.
☐	☐	2. Check tightness of connections.
☐	☐	3. Check ceramic insulators for cleanliness.
☐	☐	4. Check ceramic insulators for cracks.
☐	☐	5. Check electrodes for cleanliness.
☐	☐	6. Check electrode gap.

FAN LIMIT SWITCH

The fan and limit switch is usually a combination and single element Helix type bimetal actuated control. It serves as an operating control for the blower as well as a safety limit switch. The limit has an adjustable range and adjustable differential on the fan side. During operation, the heat created rises naturally in the furnace causing the helical shaped bimetal located in the end of the control tube to develop torque and start to twist in a counter clockwise direction. Two cams are located and attached to the other end of the rod. When the rod turns, the cams also turn. This action will close the normally open contacts and complete the circuit to the blower motor at a set temperature. When the thermostat has been satisfied, it cuts off power at the primary control and shuts down the furnace. The blower will continue to operate until the heat exchanger has cooled down at which time the fan switch opens stopping the blower operation. The fan on cycle is usually 140°F and off cycle at 90°F. Always consult the manufacturers recommendation for the correct setting. If the setting temperature is unknown, adjust the fan on cycle to blow warm air and fan off cycle to shut down prior to blowing cold air. The limit side of the switch is normally closed. If the blower malfunctions or in case of over temperature, the other cam will open the limit switch causing the furnace to shutdown. This switch is usually set at 200°F. Never allow the temperature to exceed 250°F. A thermometer can be placed in the supply duct and return duct to obtain the temperature readings. All panels and doors should be securely closed whenever operating the furnace. Operation with panels ajar or door off could permit the escape of dangerous fumes. Also, remember to use caution when working with electrical (live) circuits as dangerous shock could result.

Use the following check guide for troubleshooting the fan-limit switch on the assigned furnace.

Needs Repair or Servicing	O.K.	
☐	☐	1. Check for loose connections and burned wiring.
☐	☐	2. Check for correct voltage at the limit fan control switch.
☐	☐	3. Check malfunction of limit switch - opening too soon, or sticking contacts in open position.
☐	☐	4. Check limit for correct adjustment.
☐	☐	5. Check the fan switch for correct differential - too wide or too narrow.
☐	☐	6. Check the fan switch for slow operation during on or off cycle.
☐	☐	7. Inspect the bimetal actuated rod for cracks and other visual damage. Never rotate the shaft by hand as warping of the bimetal could result.

Needs Repair or Servicing	O.K.	
☐	☐	8. Check for defective wiring to blower assembly.
☐	☐	9. Check for correct voltage at blower motor terminals.
☐	☐	10. Check for correct blower speed, too fast or too slow. Enough or not enough air will give erratic indications.

Job Sheet HE-28g

Do the following checks to the blower assembly on the unit assigned.

Needs Repair or Servicing	O.K.	
☐	☐	1. Check to see if blower motor is operating.
☐	☐	2. Inspect the blower for security and noticeable damage: bent blades, broken blades, warping, rubbing, etc.
☐	☐	3. Check adjustment for primary air input. (Not enough air or too much air).
☐	☐	4. Check rotation of motor to see if blower assembly is installed correctly.

Job Sheet HE-28h

Do the following checks to the flue pipe on the unit assigned.

Needs Repair or Servicing	O.K.	
☐	☐	1. Check flue pipe for proper installation.
☐	☐	2. Check flue pipe for dents, holes, and any other visual damage.
☐	☐	3. Inspect flue passages for excessive soot, dirt, or other obstruction.
☐	☐	4. Check the barometric damper for visual damage and freedom of movement.
☐	☐	5. Check for proper draft with a draft guage and adjust, if required.
☐	☐	6. Check for leaks into fire box or for cracks in heating element.

MAJOR BLOCK Heating **NAME**

TASK Gas Heating

UNIT Installing & Servicing Humidifiers **TIME (est.)** **(act.)**

UNIT NO. HE-29

OBJECTIVE(S)

Install and service typical humidifiers.

START ➔ W-1 W-2 A-1 L-1 C-1 A-2 L-2
C-2

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet HE-29a
W-2 Text Assignment HE-29a
W-3
W-4
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet HE-29a
L-2 Job Sheet HE-29b
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set HE-29a
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3
C-4
C-5
C-6
C-7
C-8
C-9

I. Heating and Humidity Control

According to Webster, "Humidity is moisture, dampness or wetness, especially in the atmosphere. Humidity refers to the presence of moisture only, not the amount in the atmosphere." The amount of moisture that a given volume of air is capable of holding, varies with the temperature of the air. Warm air is capable of holding more moisture than cold air.

When heated, water and moisture converts to a vapor. This process is known as evaporation. The rate of evaporation varies with the temperature and the amount of humidity (vapor) already in the air. Humidified air slows down the evaporation rate.

"Relative humidity" is the amount of moisture in the air compared to the amount of moisture the air could hold at that temperature. When air is completely saturated, containing all the moisture it can hold a particular temperature, the relative humidity is 100%. Air in a home heated to 70° can hold about 8 grains of moisture per cubic foot. If the air actually contains only 4 grams of moisture per cubic foot it would be 50% saturated. In that case the relative humidity is 50%, which means the air contains only 50% of the moisture it is capable of holding at that temperature.
In the winter, it is not unusual for the moisture content of the outside air to be low. This does not necessarily mean that the relative humidity is low, it could be normal or high, but even so its moisture content would be low because cold air cannot hold nearly as much moisture as warm air. When cold air enters the house, it is heated, thus increasing its moisture holding capacity. If moisture is not added to this heated air, indoor relative humidity drops far below the minimum comfort range and the evaporation rate increases. This evaporation process draws moisture from every available source, including wood, leather, paper, cloth and plants. The evaporation process causes the materials to shrink as they lose water, warping and cracking takes place. Furniture is greatly affected, glue dries out, joints separate and cracks will appear, floors separate, pianos lose their tune, even carpets wear out quickly because a dry fiber breaks while a moist fiber bends.

While all these things exist, the greatest damage is done to the occupants. The most obvious result is the personal comfort of the occupants. The low humidity causes rapid evaporation of moisture from the skin. This evaporation causes the occupants to feel uncomfortable, they respond by turning the thermostat still higher resulting in even lower relative humidity within the home.

Static electricity is another annoying problem to the occupants. It also is a symptom of low humidity.

Finally, the greatest problem caused by low humidity is damage to the respiratory system. When the relative humidity drops below 35% the mucus in the nose and upper respiratory system starts to dry out, the lower the humidity falls, the more rapidly the respiratory system dries out. Because the mucous is the body's air filter, people begin to get sick when the humidity drops. Colds, flu and other respiratory ailments increase when the heating season begins.

The service technician should now be convinced that moisture must be added to a home during the heating season. The moisture added must be carefully controlled because too much moisture is also undesirable. Moisture is added to the air naturally by such things as plants, cooking, showering, bathing, even the occupants contribute when they exhale or evaporate water vapor from their skin. The normal activities of an average family of four adds an average of 3.2 gallons of water to the air each day. But, even on fairly moderate winter days in tightly constructed homes, this is not enough to raise the humidity level to the comfort range. A tightly constructed home is one which has 1/2 air change per hour. It has insulated walls and ceilings, tight fitting storm doors and windows, and weather stripping. A home of loose construction is one with no insulation, no weather stripping, no storm windows or storm doors and will have about 2 air changes per hour. A house of average construction falls in between these with about 1 air change per hour. Too much moisture in a home will cause mildew and will rot the wood on windows. When moisture in a home is too high it collects on the windows. This is because the window is cold and the dew point is rapidly reached, causing the moisture to condensate on the cold window surface. Usually condensation on inside windows is a measurement of the allowable relative humidity inside a home. It can be further assumed that if this condensation is taking place on windows, it is also probably taking place within the walls, if there is no vapor barrier. Most wall insulation has a vapor barrier (foil back) but it has become common practice to blow insulation into attics without a vapor barrier.

Therefore humidity must be controlled. It is best controlled using a central system humidifier and controlled by a humidistat. Your next assignment will explain humidifier types and humidistats. Use the following chart as a guide in setting desired inside relative humidity.

When the Outside Temperature is:		The Maximum Safe Indoor Relative Humidity is:
10 F	-	20%
0 F	-	25%
10 F	-	30%
20 F	-	25%
30 F (and above)	-	35%

Your instructor will assign a duct mounted power humidifier for installation into a heating system.

Procedure:

1. Consult the service manual for the assigned equipment.
2. Select location in the supply plenum.
3. Layout and cut opening for installation.
4. Remove lower water reservoir and hang the upper case in position.
5. Make connection to waterline. (Saddle clamp)
6. Run pipe to the humidifier.
7. Install the purge drain if applicable.
8. Reassemble the humidifier.
9. Mount the duct humidistat.
10. Make electrical connections.

Job Sheet HE-29b

Perform routine service according to the manufacturer's specifications. The instructor will assign a unit on which this activity can be performed.

Procedures:

1. Disconnect power source and water supply from the unit.
2. Consult manufacturer's service manual for service recommendations.
3. Remove purge drain tubing and water reservoir.
4. Clean the various parts.
5. Remove media wheel.
6. Reposition or replace the valve button in the float.
7. Reassemble and adjust water level.